



Environmental Statement

Chapter 9. Fish including Recreational and Commercial Fisheries



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9.0 Fish, including Recreational and Commercial Fisheries

9.1 Introduction

- 9.1.1.1 This Chapter describes the predicted construction, operational and decommissioning effects of the Project on the ecology of fish and shellfish within the area of the Lagoon and Offshore Works and the wider area, and on commercial and recreational fishing interests. Designated species, along with commercial and recreational fish and shellfish resources have been identified through an initial desk study, as well as field surveys.

9.2 Legislation and data review

- 9.2.1.1 An overview of the policy and legislation relevant to this assessment can be found in Appendix 9.1 (Volume 3). Baseline characterisation of fish and shellfish data was undertaken primarily through a desktop study of published literature. Consultation with local fishermen and fishing union representatives also yielded useful information on the distribution and presence of commercially exploited species in the relevant area. A summary is provided in this chapter with the full results of these studies being presented in the fish and shellfish baseline report (Appendix 9.1, Volume 3).

9.3 Methodology overview

9.3.1 Consultation

- 9.3.1.1 As part of the EIA process a number of consultations were undertaken. Consultees comprised statutory authorities and private stakeholders and included the following: Natural Resources Wales (NRW) (formerly three institutions: Countryside Council for Wales, Environment Agency Wales and Forestry Commission Wales); the Marine Management Organisation (MMO); South and West Wales Fishing Communities (SWWFC) and the Angling Trust. Written responses received were based on direct consultations and feedback from the Preliminary Environmental Information Report (TLSB, 2013) and have been used to develop the scope of the assessment. Details of the consultation responses relevant to this assessment are presented in the Consultation Report that accompanies the Development Consent Order. Key aspects raised comprise:

- I. Impacts of construction, notably:
 - i. adverse effects of increased suspended solids levels;
 - ii. underwater noise emissions from piling and dredging on salmon *Salmo salar*, sea trout *Salmo trutta*, European eel *Anguilla anguilla* and other migratory species and resident fish such as sandeel *Ammodytes spp.*;
 - iii. effects of sedimentation on commercial shellfish species; and
 - iv. the potential for release of toxic metals from sediments.
- II. Extent of temporary and permanent habitat loss.
- III. Time taken for disturbed habitat to recover post-construction.
- IV. Potential for turbines to cause fish injuries and mortalities and as a result to adversely affect salmon and sea trout fishing in rivers entering Swansea Bay.
- V. Potential for the Lagoon walls to fragment fish habitat within the Bay and to disrupt fish migration.



- VI. Potential for migratory fish to become trapped within the Lagoon, once operational, and to be exposed to poor water quality from sewage outfall.
- VII. Effects of the scheme on keystone species such as sandeel.
- VIII. Effect on herring *Clupea harengus* spawning within the Bay.
- IX. Effect of power cables on fish migratory behaviour.
- X. Effects on any Special Areas of Conservation.
- XI. Effects on Water Framework Directive classifications.
- XII. Effects on protected species.
- XIII. Effects on property rights of fishery owners on the Tawe, Neath and other local rivers.
- XIV. Increased steaming times for commercial and sport fishing vessels having to pass around the Lagoon to reach fishing grounds.
- XV. Opportunities for mariculture.
- XVI. Requirements for post-commissioning monitoring.
- XVII. In-combination effects from other projects in the area.

9.3.2 Limitations

- 9.3.2.1 In carrying out the surveys and other assessments for this Chapter certain limitations in data and technique apply. These are presented in Appendix 9.5, Volume 3.

9.3.3 Site-specific surveys methodology

- 9.3.3.1 Further to the desktop study, data is being gathered through a series of ongoing seasonal fisheries surveys, based on standardised EU Water Framework Directive (WFD) (Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy) survey protocols. Four quarterly surveys were completed in 2013.
- 9.3.3.2 For a detailed account of survey methodologies, please refer to Appendix 9.2 Quarterly survey reports (Volume 3). A summary of the methods used in site-specific surveys is provided below:
 - i. Four surveys involving intertidal and subtidal techniques were conducted: Quarter one (winter 2012); Quarter two (spring 2013); Quarter three (summer 2013) and Quarter four (autumn 2013).
 - ii. Intertidal surveys involved two surveying methods: a beach seine net (43 m long by 4 m deep, with 6.5mm knotless mesh) set from a small rigid vessel; and a Riley push-net (1.5 m wide by 30 cm deep with 1 mm fry mesh) used from the shore.
 - iii. The subtidal surveys were carried out from a 12.1 m mono-hull trawler using both otter and beam trawls. The specification of the nets deployed during these surveys is detailed in Appendix 9.2 (Volume 3).
 - iv. For each survey the catch was identified to species level and measured to the nearest millimetre; fish were sub-sampled when > 50 specimens of the same species were captured.

- 9.3.3.3 The aim of the surveys was to provide an up-to-date characterisation of fish resources in the study area, which, combined with regional information, can be compared to provide the basis for evaluating the importance of species, or groups of species, as 'valued ecological receptors' for consideration in the impact assessment.

Study area

- 9.3.3.4 For the purposes of defining potential receptors, a study area has been identified. This is divided into is 'near-field' and 'far-field' zones of influence of the Project, the latter zone being the likely extent of the wider area that may be affected. The near-field and far-field have been identified following extensive hydraulic modelling and consultation with statutory bodies, including the Countryside Council for Wales and the Environment Agency (now both part of NRW).
- 9.3.3.5 The near-field zone (Figure 9.1) comprises Swansea Bay (NGR SS 630910). The Bay is approximately 12 km wide (from Mumbles Head to Port Talbot) with an area of some 50 km². The seabed in the Bay is largely composed of muddy sand, with rock outcrops and cobbles occurring mainly on the Western side towards Mumbles. Bathymetry across the Bay is fairly regular, with a 5 m bathymetric contour present around 5 km offshore, and deeper areas (> 20 m) South of Mumbles Head. The subtidal area in this study area is around 4155 ha. Large areas of intertidal bed become exposed on low tides, and this area equates to around 1870 ha.

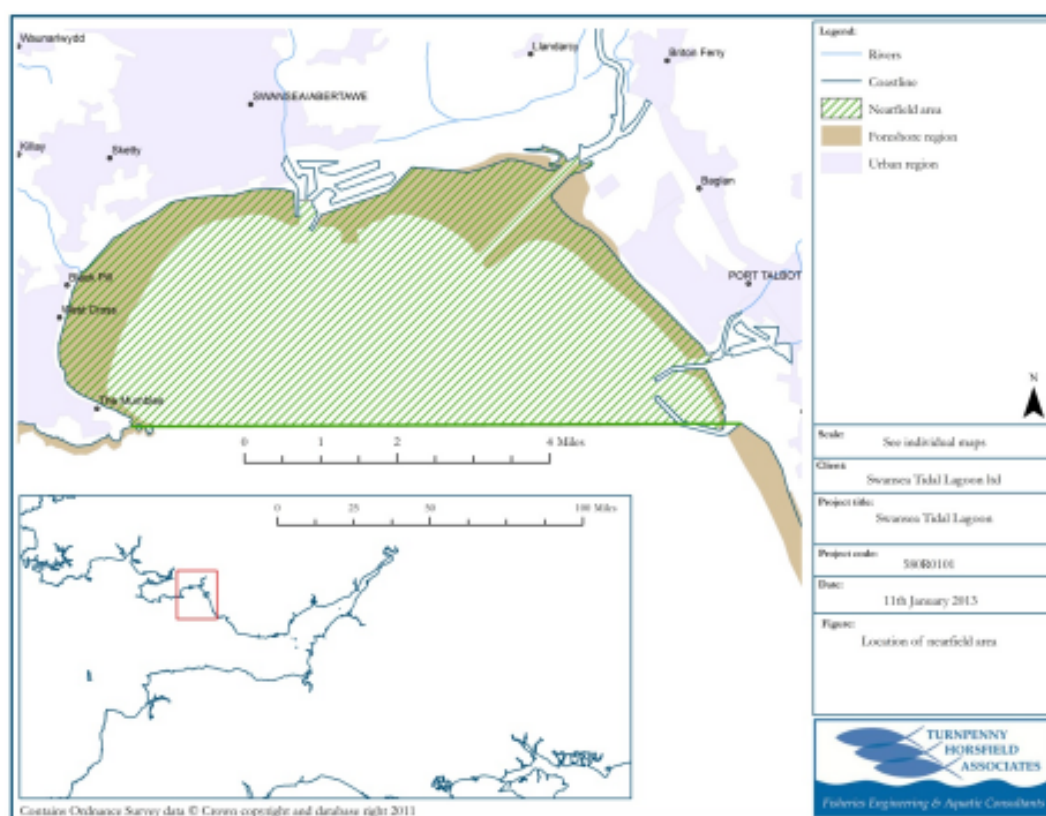


Figure 9.1 Map showing location of the near-field area

- 9.3.3.6 The far-field zone (Figure 9.2), as well as encompassing Swansea Bay itself, includes some ten miles of the coastline to the West of Swansea. This section of the Gower Peninsula is made up of a series of bays, alternately rocky and sandy, comprising: Langland Bay, Caswell Bay, Oxwich Bay and Port Eynon Bay. The far-field zone also encompasses coastline south-east of Port Talbot Docks. To take account of migratory

fish populations, the Rivers Afan, Neath and Tawe were included in the far-field zone of impact.

- 9.3.3.7 EIA is an iterative process and therefore, the near-field and far-field zones have been the subject of review as assessment has progressed. As detailed in the assessments given in Section 9.6, the residual impact of the Project on migratory fish in the principal rivers (Rivers Afan, Neath, Tawe and Kenfig) is **minor** to **insignificant**. Consequently, whilst consideration was given to including other rivers in the study area, it has been possible to exclude such rivers outside Swansea Bay, including the River Ogmore, from the assessment. This has been possible on the grounds that any effects on other rivers will also be negligible owing to their hydrographic isolation from Swansea Bay tidal circulation, particularly given that even those rivers within Swansea Bay experience limited effects.

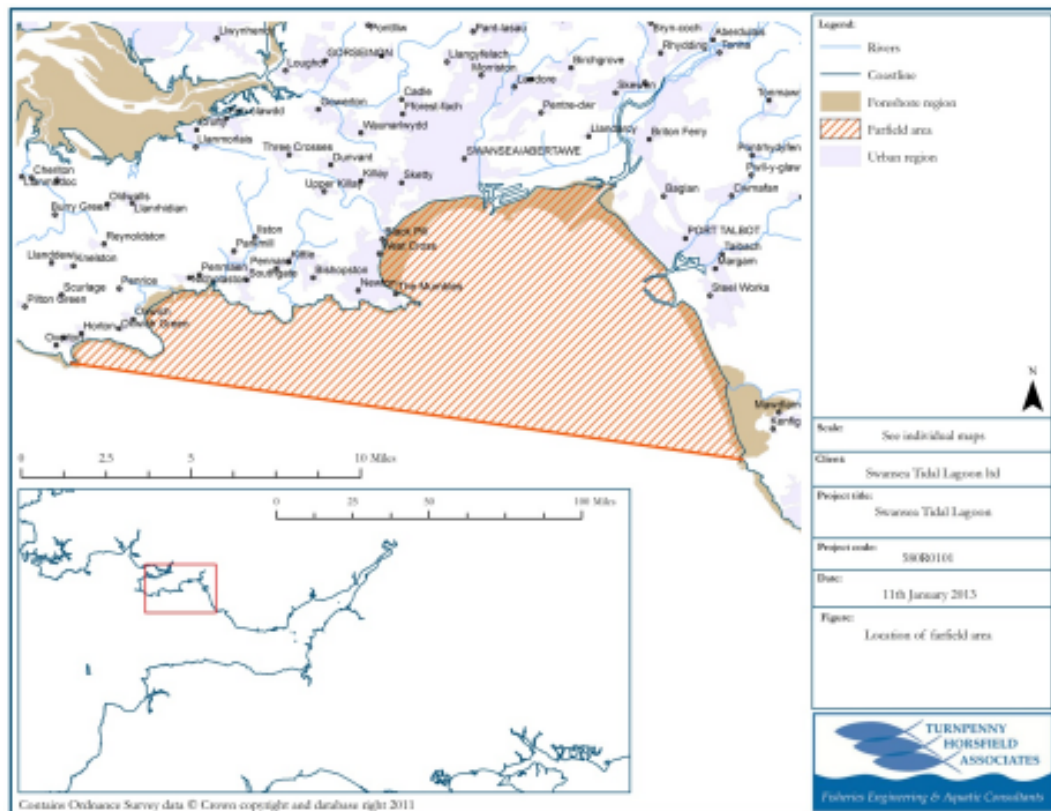


Figure 9.2 Map showing location of the far-field area

- 9.3.3.8 The importance of a species as commercial catch is considered based on the Marine Management Organisation datasets within the geographical extents of three International Council for the Exploration of the Sea (ICES) statistical rectangles (32E5; 32E6 and 31E6; Figure 9.3). They are currently the smallest spatial unit used by the European Community (EC) and its Member States to assess fishing activity in European Waters.
- 9.3.3.9 The final balancing assessment, in terms of both of identification of a resource as a receptor, and ascription of a significance level to it, is based on expert judgement.

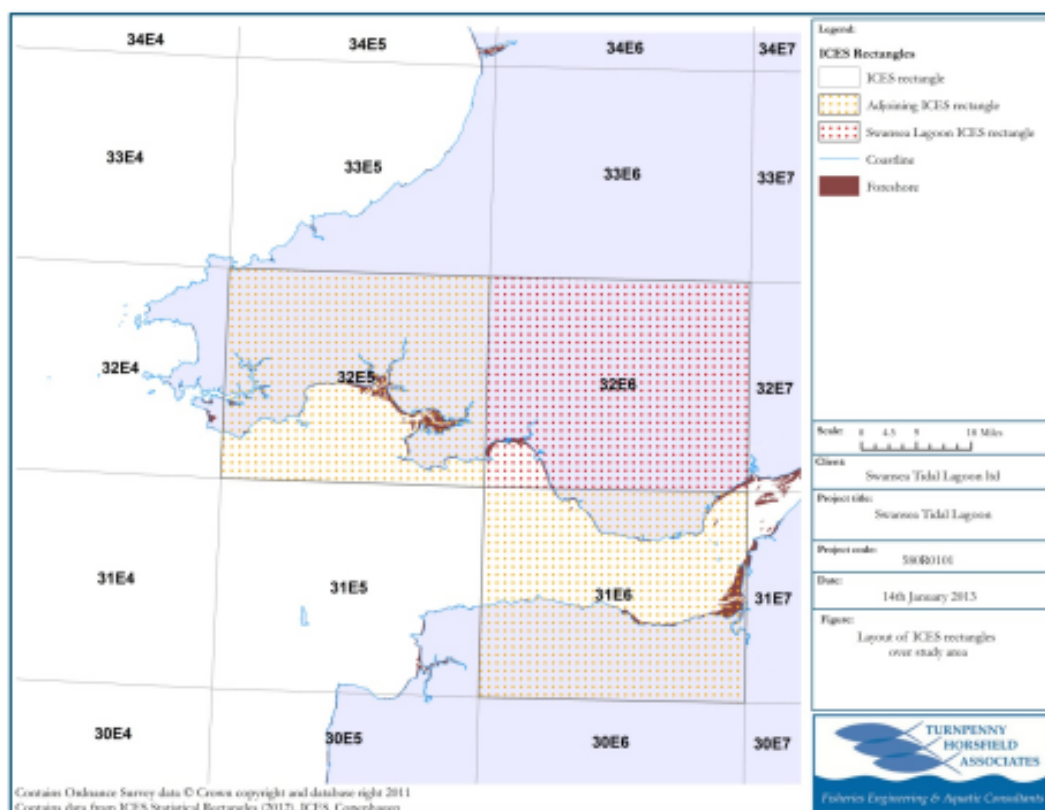


Figure 9.3 ICES statistical rectangles, used to inform the value of commercial species in the area

9.3.4 Generic assessment overview

- 9.3.4.1 Within the section below, generic assessment criteria applicable to fish and shellfish, commercial fishing and recreational fishing are presented. More specific criteria, such as the value of receptors within each area assessed, are given separately.
- 9.3.4.2 The assessments provided aim to identify and quantify the likely significant effects that could arise from all stages (construction, operation and decommissioning) of the Project. Cumulative impacts between the Project and other projects and plans were also considered. For any significant effects, mitigation measures are presented and residual effects identified. Value and magnitude assessments are provided below for fish and shellfish, commercial fishing and recreational fishing.
- 9.3.4.3 The overall impact assessment approach used is in line with the most recent guidance from the Chartered Institute of Ecology and Environmental Management (IEEM, 2010). Guidance on the EIA process has been sought from the following sources:
- Guidelines for Ecological Impact Assessment in Britain and Ireland. Marine and Coastal, Final Document (IEEM, 2010);
 - Guidance note for Environmental Impact Assessment in Respect of FEPA and CPA requirements (DEFRA, 2004); and
 - Overarching National Policy Statement for Energy (EN-1) and the National Policy Statement for Renewable Energy Infrastructure (EN-3) (DECC, 2011a; 2011b).



- 9.3.4.4 The National Policy Statements applicable to nationally significant infrastructure projects, such as the Project do not expressly address assessment of tidal range generation projects. However, they offer advice on potential impacts of offshore renewable energy generation schemes, and that advice is generally transposable to the Project. Even where not directly applicable, National Policy Statements remain important and relevant matters for the decision maker to consider.
- 9.3.4.5 Additionally, the implications of the following EIA regulations and legislation have been taken into consideration when compiling this document:
- i. Conservation of Habitats and Species Regulations (SI 2010/490);
 - ii. Offshore Marine Conservation Regulations 2007 (SI 2007/1842); and
 - iii. Wildlife and Countryside Act 1981.
 - iv. Water Framework Directive (Directive 2000/60/EC)
- 9.3.4.6 For the purposes of this assessment the following standard EIA criteria have been taken into account to determine the significance of possible impacts:
- I. Magnitude of the impact;
 - II. Spatial extent of the impact;
 - III. Duration of the impact;
 - IV. Likelihood of occurrence; and
 - V. Confidence in accuracy of predicted impact.
- 9.3.4.7 Confidence in the predictions of the assessment has been assigned according to a three point scale based on expert judgement:
- 1) **High** – the confidence in the prediction is very high and conclusions are primarily informed through data; some expert judgment has been used;
 - 2) **Probable** – the confidence in the prediction is likely and conclusions are based on a balance of data and expert judgement; and
 - 3) **Uncertain** – The outcome is unclear and conclusions are significantly based on expert judgement.
- 9.3.4.8 For the three phases of the Project, potential impacts were identified as follows:
- 9.3.4.9 During **construction**, the following potential impacts were examined: increases in suspended sediment and sediment deposition; increases in underwater noise and vibration; increases in artificial light emissions; habitat modification; habitat loss and during dewatering of cofferdam; and entrainment from draghead.
- 9.3.4.10 During **operation**, the following potential impacts were examined: increases in suspended sediment and deposition; habitat fragmentation and isolation; habitat modification; increased predation; entrainment from draghead; entrainment and injury risk from the turbines using fish behaviour modelling (individual based modelling, IBM) and turbine injury rate modelling (using a turbine passage fish injury rate model (STRIKER™ v.4)); entrainment and injury risk from the sluices; waterborne noise and vibration from turbines; increases in artificial light emissions; water quality; creation of electromagnetic fields; waterborne noise and vibration from recreational activities; and



increased pressure on fish populations as a result of recreational angling associated with the Project.

- 9.3.4.11 During **decommissioning**, the following potential effects were examined: increases in suspended sediment and sediment deposition; increase in underwater noise and vibration; and improved connectivity between habitats within and outside the Lagoon.
- 9.3.4.12 In addition, the potential impacts of the Project in-combination with other plans and projects were assessed. The assessment examined: the increase in suspended sediment and deposition; increase in subsea noise and vibration levels; habitat modification; habitat fragmentation and isolation; and entrainment by turbines and water abstractions.
- 9.3.4.13 For each of the assessments, the potential impacts were examined and the significance of the effect identified as described in Section 9.2.5, Section 9.2.6 and Section 9.2.7. Impacts that are 'Moderate' or 'Major' are regarded as being significant for the purposes of the Infrastructure Planning (Environmental Impact Assessment) Regulations 2009 (the 'EIA Regulations') (see Chapter 2, EIA Process and Assessment of Significance). For significant impacts, mitigation measures have been presented and residual impacts outlined. In addition, mitigation has been included in certain cases for impacts that have been identified as not significant.
- 9.3.4.14 The following section describes the methodology used to assess the significance of potential impacts on fish and shellfish.
- 9.3.4.15 This ES proceeds on the basis of the outline construction programme as discussed in Chapter 4, Section 4.5.2, which anticipates construction starting in 2015 and with the main construction lasting for about three years. The assessments contained in this chapter are not materially sensitive to works commencing within the anticipated validity of the Development Consent Order, which is five years, or to an extension of (say) a further year-or-so.

9.3.5 Fish and shellfish assessment overview

Definition of valued ecological receptors

- 9.3.5.1 The value attributed to ecological features, such as biotopes or species, is dependent on both their overall biodiversity/ecosystem services as well as their, social and economic value within a relevant geographic framework (IEEM, 2010).
- 9.3.5.2 One of the primary resources for determining the potential value of an ecological receptor is the conservation designations from which it derives. Potential value is generally well established for internationally protected sites or species (e.g. a species or site designated under the Habitats Directive). However, for sites of local value, or species which have not been formally protected through legislation, a value criterion can be harder to define. The importance of such features may be identified through analysis of various resources, such as online databases (e.g. International Union for Conservation of Nature (IUCN) red list) and other publications, as well as expert judgement.
- 9.3.5.3 The following table identifies the criteria which have been adopted to determine the ecological significance of Valued Ecological Receptors (VERs) within the geographic framework pertinent to the proposed development. Identification of VERs may be based on multiple criteria (Table 9.1).

Table 9.1 Geographic frame of reference and associated sensitivity used to determine the value the ecological receptors in the Swansea Bay Tidal Lagoon study area

Value of VER	Criteria Which Defines Value
International / Very High	Regularly occurring species protected under international law.
National / High	Species protected under national law. UK BAP priority species (including grouped action plans) that have nationally important populations within the study area. Species which have primary spawning/nursery areas (high intensity) within the study site.
Regional / Medium	UK BAP priority species (including grouped action plans) that have regionally important populations within the study area i.e. are locally widespread and/or abundant. Species which have secondary spawning/nursery areas (low intensity) within the study site. Species that are of commercial value to the fisheries which operate within Swansea Bay.
Local / Low	Species common throughout the UK and present within the study area. Species considered to enrich the ecological resource within the locality (keystone species).

9.3.5.4 Valued ecological receptors identified within the study area for fish and shellfish are listed in Table 9.2. Valuation of importance is based on their conservation value, distribution and status within the potential zone of impact, the spatial extent of spawning and nursery areas, and migratory activity, as well as importance as commercial or recreational species.

9.3.5.5 Some features may not be of specific conservation interest in themselves, but can provide a key ecological function in support of a more valuable feature.

Table 9.2 Fish and Shellfish Valued Ecological Receptors within the Swansea Bay Tidal Lagoon study area and their relative geographical importance

VERs	Value	Justification for inclusion
Migratory fish species		
European eel, allis shad (<i>Alosa alosa</i>), twaite shad (<i>Alosa fallax</i>) and sea lamprey (<i>Petromyzon marinus</i>)	International importance	European eel and shad are of international conservation importance; they do not spawn within the Bay or adjacent waterbodies, but migrate through and/or live their adult life within them. European eel are critically endangered (IUCN Red List of Threatened Species. Version 2013.2. < www.iucnredlist.org >. Downloaded on 17 January 2014). Sea lamprey are of international conservation importance; there are anecdotal records of them spawning in low density within the lower reaches of adjacent water bodies. Adults are known to migrate through or forage within the Bay and they may contribute to populations within adjacent SAC's.
Other diadromous fish (Atlantic salmon, river lamprey <i>Lampetra fluviatilis</i> and sea trout)	National importance	UK BAP species. Annex II species not directly associated with a SAC. Salmonid species are valuable socio-economically and targeted in recreational fisheries within the study area.
Other fish and shellfish		
Common sole	National importance	UK BAP grouped species with a primary nursery ground within Swansea Bay. Commercially exploited.

VERs	Value	Justification for inclusion
Herring	Regional importance	UK BAP Priority species currently not exploited through targeted fisheries; spawning is known to occur within the area and it has been identified as a low intensity nursery zone by CEFAS through targeted planktonic surveys; an important prey species for many piscivorous predators.
Sandeel	Local importance	An important prey species for a range of piscivorous fish and birds. Resident populations occur on suitable substrate across the Bay.
Other demersal and pelagic species	Mixed regional and local importance	Some species of conservation (UK BAP) and commercial interest (for a full summary see Appendix 9.1, Volume 3). May be resident or seasonally present within the Bay.
Commercial shellfish	Regional importance	Commercially important species including edible crab <i>Cancer pagurus</i> , cockle <i>Cerastoderma edule</i> , spider crab <i>Maja squinado</i> , velvet swimming crab <i>Necora puber</i> , whelk <i>Buccinum undatum</i> and lobster <i>Homarus gammarus</i> .

Assessment of significance of effect on VERs

9.3.5.6 In order to provide a consistent framework for considering and evaluating impacts, a two stage process has been adopted, involving:

- The establishment of a magnitude value for impacts on VERs, based on an understanding of their sensitivity, together with a characterisation of the impact i.e. its temporal and spatial characteristics. This value is rated on a six-point scale (Table 9.3); and
- A definition of significance based on the geographical frame of reference/value of a receptor and magnitude of impact. A matrix is used to give a “significance descriptor” (Table 9.4).

Table 9.3 Criteria used to classify the magnitude of impacts on fish and shellfish

Potential consequence of impact on VER	Magnitude
The impact would have a serious, non-reversible effect over the integrity of the VER. Activities predicted to occur and affect the VER continuously over the long term or during sensitive life stages.	High
The integrity of the overall VER would not be affected but there may be some effect on the overall conservation objectives for that species within a given geographical area. There is the potential for activities to regularly disrupt the receptors, over the medium to short term and during sensitive life stages.	Medium
Species are subjected to a limited adverse effect. Disturbance to the population size is within parameters of natural variability. Activities are likely to be intermittent and irregular over the medium to short term.	Low
A small observable effect is predicted. Disturbance is expected to fall within natural variability. Impacts are limited to the area in the immediate vicinity of the development.	Negligible
Although it is not always possible to state categorically that there will be no impact on a receptor the term ‘neutral’ will be used where the level of exposure is considered to be less than the tolerance of the receptor, therefore an impact is unlikely. Or there will be no impact at all on the species in question.	Neutral
The change is likely to prove beneficial to the VER.	Positive

Table 9.4 Significance of an impact resulting from the combination of receptor sensitivity/value and the magnitude of the effect upon it

Value/importance	Magnitude (Positive/Adverse)				
	Neutral	Negligible	Low	Medium	High
Very High/International	No impact	Minor to insignificant	Moderate to Minor	Major	Major
High/National	No impact	Insignificant	Minor	Moderate	Major
Medium/regional	No impact	Insignificant	Minor	Moderate	Moderate
Low/local	No impact	Insignificant	Insignificant	Minor	Minor

N.B. Within the significance matrix an impact of positive magnitude can have the same significance value as an adverse effect (i.e. negligible to high).

- 9.3.5.7 As well as for ecological receptors, the above significance matrix has been used for commercial and recreational assessments. However, for each of those, different value and magnitude tables have been produced (see Tables 9.7 and 9.9).

Methodology for the assessment of the significance of fish mortality associated with the Project

- 9.3.5.8 There are no formal UK regulatory guidelines for assessing the significance of fish mortality levels caused by operation of hydropower facilities or other types of engineering schemes and therefore any assessment must be based on expert judgment. A number of cases presented below provide examples of how such judgments have been made in other applications, and are used to develop a frame of reference or scale for assessing the magnitude of fish mortalities in the tidal lagoon context. The sustainable management of marine fish stocks is based, for example, on the estimation of the maximum sustainable yield from analysis of stock-recruitment curves following principles established by Beverton and Holt (1957). It is not untypical for marine fish stocks to be exploited at annual fishing mortality rates of > 50 %, on top of natural mortality. The principle behind this is that sufficient brood-stock remain in the population to maintain stock levels from year to year.
- 9.3.5.9 No precedent exists for assessing quantitative impact significance of tidal range power schemes on fish; the La Rance scheme in Brittany being the only fully operational example in the western world of comparable scale, although even that project is dissimilar in terms of the location of the scheme vis-à-vis riverine environments.
- 9.3.5.10 The principle of assessing impacts of a single power generation facility on marine fish stocks was devised for the assessment of cooling water abstraction impacts at the Sizewell nuclear stations (Suffolk) for the Sizewell 'B' Public Inquiry (Turnpenny, 1988; Turnpenny & Taylor, 2000). The process involved estimating mortality rates in the context of stock components at various geographic scales, from local (the single adjacent ICES rectangle) to international (whole North Sea). Estimated power station-related losses at Sizewell 'A' varied according to species and geographic scale of reference, and ranged from less than 0.1% of North Sea stocks as a whole, to between 0.1 % and 6.4 % of commercial landings from the local area. Commercial fishing exploitation rates in the North Sea were estimated at between 15 % and 53 %, depending on species. No objection was lodged at the Inquiry in relation to predicted fisheries impacts of the power station. This approach is now accepted as best practice for fisheries impact assessments for all coastal and estuarine-sited power stations in England and Wales (Environment Agency, 2010a).



- 9.3.5.11 In another application, the Thames Tideway Strategy Group, comprising representatives from the Environment Agency, Port of London Authority, Thames Water and others, developed water quality standards for the regulation of dissolved oxygen levels in the Thames Tideway to protect fish kills associated with storm discharges combined sewer outfalls (Turnpenny et al., 2004). The efficacy of different standards was compared using an ecotoxicological model, the Tideway Fish Risk Model (TFRM). The TFRM considers annual mortality rates of up to 10 % to be sustainable for all species (i.e. the integrity of the population would not be threatened), and up to 30 % for longer-lived species such as bass *Dicentrarchus labrax* and salmon. These acceptable percentage losses assumed that there were no other anthropogenic sources of mortality, such as fishing. The 10 % value was also considered to be the practical minimum change likely to be detectable through ongoing routine WFD Transitional and Coastal (TrAC) water fish surveys.
- 9.3.5.12 Mortalities of seaward-migrating salmonid smolts, that may have to pass multiple hydropower stations, have attracted particular interest in this regard; in large North American rivers, such as the Columbia River, serial smolt losses may be in the order of 10 to 40 %. In one US example, the National Marine Fisheries Service required improvements to the Pacificorp's Condit Hydroelectric Project for the scheme to achieve 95 % survival of smolts migrating downstream past the scheme (Wellner, 2007).
- 9.3.5.13 In the UK there has been ongoing discussion of what value constitutes an acceptable fish loss associated with fish passage of a single new hydropower development. This issue is complicated by site-specific factors, and in almost all cases by the lack of detailed long-term quantitative data that would be required to understand the population dynamics of the fish stock in question. It therefore becomes a matter for expert judgement rather than quantitative scientific assessment. During the preparation of the Environment Agency's first (2007) Hydropower Good Practice Guidelines, an industry-regulator stakeholder consultation meeting was held in which there was general consensus that the target should be to achieve at least a 95 % smolt survival rate past a hydropower scheme where it was the only one on a river system, and at least 98 % survival per scheme where multiple schemes resulted in serial exposure on the same river. These targets were not however formalised within the 2009 Guidelines.
- 9.3.5.14 In light of the above variations in assessment criteria, fish mortality assessments associated with turbine passage in the context of the Project, which is an offshore development, have been assessed using the conservative criteria provided in Table 9.5.

Table 9.5 Assessment criteria for turbine passage

Impact Magnitude	Annual Mortality Rate Due to Project
High	> 10 %
Medium	2.1 - 10 %
Low	1 - 2.0 %
Negligible	< 1 %

- 9.3.5.15 Fish mortality rates for the principal rivers within Swansea Bay (Tawe, Neath, Afan), and for marine fish present within the Bay, have been calculated as percentages of stocks frequenting the near-field hydraulic area only (see Table 9.22).
- 9.3.5.16 To examine fish mortality rates, baseline data on fish within the study area have been examined and two models have been developed:
- Fish behaviour modelling.** "individual-based modelling" (IBM) has been used to predict how fish of a given species will react to water currents and topographical



features. IBM modelling allows the frequency of turbine encounters by fish to be estimated, and also the number of times a specific type of fish, such as a salmon, is expected to pass through a turbine as a result of tidal incursions and excursions. It also provides an indication of the likely routes to be followed by migratory fish based on cues to which they are known to respond.

- ii. **Turbine injury rate modelling.** The second stage used a turbine passage fish injury rate model (STRIKER™ v.4), optimized for ‘tidal range’ turbines, to estimate the percentage of fish passing through a turbine, estimated by the IBM, that are likely to be injured. STRIKER™ v.4 estimates injuries resulting from collision with the fixed or rotating turbine blades, or from other physical stresses such as pressure change, hydraulic shear and turbulence.

9.3.5.17 Further details of these models are presented in Section 9.4.3.

9.3.6 Commercial fisheries assessment overview

9.3.6.1 Guidance on the commercial fisheries assessment has been taken from the National Policy Statement for Renewable Energy Infrastructure EN-3 and additional publications from DEFRA (2004). Possible impacts arising from renewable projects on commercial fisheries include the following:

- i. Complete loss of, or restricted access to, traditional fishing grounds during construction, operation and decommissioning;
- ii. Safety issues for vessels;
- iii. Interference with fishing activities;
- iv. Increased steaming times to fishing grounds;
- v. Obstacles or obstruction on the seabed as a result of the construction work; and;
- vi. Any further concerns raised by local fishermen and fishing organisations were also included in the assessment.

Definition of commercial fisheries receptors

9.3.6.2 For commercial fisheries the principal receptors are expected to be the local inshore fishing vessels from Swansea Port, though they may also include vessels from other ports including:

- I. Burry Port (25 km);
- II. Saundersfoot (56 km);
- III. Milford Haven (78 km);
- IV. Fishguard (87 km); and
- V. Tenby (56 km).

9.3.6.3 In addition to the above ports, overseas fishing interests have also been identified. Landings data indicate that Belgian vessels are the only other commercial fishing vessels to have operated within ICES Rectangle 32E6 in recent years. For more detailed description of commercial fisheries within the region please see (see Appendix 9.2, Volume 3).



- 9.3.6.4 The following table (Table 9.6) identifies the criteria which have been adopted to determine the value of commercial fishery receptors within the geographic framework pertinent to the proposed development.

Table 9.6 Potential value of commercial fishing receptors in the Swansea Bay Tidal Lagoon study area

Value of Receptor	Criteria Which Defines Value
Very High	Internationally valued fishing fleets contributing significantly to the EU economy
High	Nationally valued fishing fleets contributing significantly to the Welsh economy
Medium	Regional fishing fleet which contributes significantly to adjacent countries
Low	Small fishing fleet contributing at the local economy scale

- 9.3.6.5 Owing to the very low amounts of commercial fishing by a limited number of vessels occurring within Swansea Bay and ICES rectangle 32E6 as a whole, the commercial fishery receptors have been judged as being of **low value**.

Assessment of significance of effects on commercial fisheries receptors

- 9.3.6.6 In order to provide a consistent framework for considering and evaluating impacts, a two stage process has been adopted involving:
- The establishment of a magnitude value for impacts on commercial fisheries receptors, based on an understanding of their sensitivity, together with a characterisation of the impact i.e. its temporal and spatial characteristics. This value is rated on a six-point scale (Table 9.7); and
 - A definition of significance based on the value of a receptor and magnitude of impact. A matrix is used to give a “significance descriptor” (Table 9.4).

Table 9.7 Criteria used to classify the magnitude of impacts on commercial fisheries

Potential consequence of impact on VER	Magnitude
Commercial fishing activity on traditional fishing grounds will be severely affected by the project and/or associated construction activities. Permanent (>3 years) interference to fishing grounds will occur.	High
Commercial fishing activity on traditional fishing grounds will be significantly affected by the project and/or associated construction activities. Long-term (6 months to 3 years) interference to fishing grounds will occur.	Medium
Commercial fishing activity on traditional fishing grounds will be affected by the project and/or associated construction activities. Medium-term (1 to 6 months) interference to fishing grounds will occur.	Low
Commercial fishing activity on traditional fishing grounds will remain largely unaffected the Project and/or associated construction activity. Intermittent and temporary interference to fishing grounds will occur.	Negligible
Although it is not always possible to state categorically that there will be no impact on a receptor the term neutral will be used where the level of exposure is considered to be analogous to natural variation.	Neutral
The change is likely to prove positive to the status of the fishery.	Positive



9.3.7 Recreational fisheries assessment overview

Definition of recreational fisheries receptors

9.3.7.1 In this section the principal receptors have been assessed as:

- i. Boat-based angling (including charter fishing boats and private vessels used for sea angling);
- ii. Shore-based angling (sea anglers fishing from the shore, harbour walls etc); and
- iii. Salmon and sea trout fisheries (including fishing rights owners, lease-holders and clubs on rivers).

9.3.7.2 Refer to Appendix 9.1 (Volume 3) for a description of the recreational fishing interests within the Bay and wider region.

9.3.7.3 The following table (Table 9.8) identifies the criteria which have been adopted to determine the value of recreational fishery receptors within the geographic framework pertinent to the Project.

Table 9.8 Potential value of recreational fishing receptors in the Swansea Bay Tidal Lagoon study area

Value of Receptor	Criteria Which Defines Value
National/High	Nationally valued recreational fishery contributing significantly to the Welsh economy
Regional/Medium	Regionally valued recreational fishery contributing to the economy of several counties
Local/Low	Locally valued recreational fishery supporting the local economy

9.3.7.4 The principal receptors have been ascribed values as follows:

- i. Boat-based angling has been assessed as being of **Local** importance due to the low number of commercial charters which operate in the area and the limited number of private vessels which fish within the Bay.
- ii. Shore-based angling has been assessed as being of **Local** importance due to the fact that the impact is limited to a small area that is not of particular note in terms of its angling opportunities. Excellent shore angling is, and will continue to be, available on the western harbour wall at Swansea, as well as elsewhere in the Bay.
- iii. Salmon and sea trout fisheries have been assessed as being of **National** importance owing to their economic value to the Welsh economy.

Assessment of significance of effects on recreational fisheries receptors

9.3.7.5 In order to provide a consistent framework for considering and evaluating impacts, a two stage process has been adopted involving:

- I. The establishment of a magnitude value for impacts on recreational fisheries receptors, based on an understanding of their sensitivity, together with a characterisation of the impact i.e. its temporal and spatial characteristics. This value is rated on a six-point scale (Table 9.9); and
- II. A definition of significance based on the value of a receptor and magnitude of impact. A matrix is used to give a “significance descriptor” (Table 9.4).

Table 9.9 Criteria used to classify the magnitude of impacts on recreational fisheries

Potential consequence of impact on VER	Magnitude
Recreational fishing activity on traditional fishing grounds and adjacent watercourses will be severely affected by the project and/or associated construction activities. Permanent (> 3 years) interference to fishing grounds will occur.	High
Recreational fishing activity on traditional fishing grounds and adjacent watercourses will be severely affected by the project and/or associated construction activities. Long-term (> 6 months to 3 years) interference to fishing grounds will occur.	Medium
Recreational fishing activity on traditional fishing grounds and adjacent watercourses will be severely affected by the project and/or associated construction activities. Permanent (> 1 to 6 months) interference to fishing grounds will occur.	Low
Recreational fishing activity on traditional fishing grounds and adjacent watercourses will remain largely unaffected the Project and/or associated construction activity. Intermittent and temporary interference to fishing grounds will occur.	Negligible
Although it is not always possible to state categorically that there will be no impact on a receptor the term neutral will be used where the level of exposure is considered to analogous to natural variation.	Neutral
The change is likely to prove positive to the status of the fishery.	Positive

9.4 Fish and Shellfish

9.4.1 Fish and shellfish baseline characterisation

- 9.4.1.1 The broader fish community of the Swansea Bay region can be categorised as demersal, pelagic and benthopelagic. Common demersal species include: flatfish, such as plaice *Pleuronectes platessa*; common sole *Solea solea*; flounder *Platichthys flesus*; dab *Limanda limanda*; several species of ray *Raja* spp.; and small-bodied species such as dragonet *Callionymus lyra*, grey gurnard *Eutrigla gurnardus* and goby species *Pomatoschistus* spp. The pelagic fish community within the Swansea Bay is characterised by an abundance of herring and sprat *Sprattus sprattus*, whilst sandeel are amongst the most common benthopelagic fish.
- 9.4.1.2 Fish abundance is seasonal and numbers of fish fluctuate significantly between the summer and winter months. Juvenile flatfish dominate the shallow sloping littoral sandflats during the summer, species include flounder, common sole, turbot *Scophthalmus maximus* and plaice. These flatfish are found in relatively high abundances across the Bay. During winter months, fish push further offshore, and the community becomes dominated by gadoids (e.g. whiting *Merlangius merlangus*, pouting *Trisopterus luscus*, poor cod *Trisopterus minutus*). Populations of gobies peak over the winter months. Autumnal abundance is linked to the arrival of juveniles spawned in the spring/summer of the year.
- 9.4.1.3 The Swansea Bay region supports a number of diadromous (migratory) fish species. These species are all priority species of conservation importance under the UK Biodiversity Action Plan (UK BAP). Diadromous fish move between the sea and freshwater and thus migrate through Swansea Bay into and out of one of the four primary rivers draining into the embayment: the Rivers Tawe, Neath, Afan, and Kenfig.



- 9.4.1.4 Spawning populations of Atlantic salmon, sea trout, eel and river lamprey *Lampetra fluviatilis* are regularly recorded in Swansea Bay and connected water bodies. Sea lamprey *Petromyzon marinus* and Twaite shad *Alosa fallax* are sporadically recorded within the Bay, though no evidence has been provided to indicate significant spawning occurring in the locality from these two species.
- 9.4.1.5 Site specific surveys of the area carried out in 2013 as part of the Project suggest that fish populations identified reflect that of the wider region, as described by Claridge et al. (1986). A total of 55 species were captured during the site-specific intertidal and subtidal surveys (Figure 9.4; see Appendix 9.2, Volume 3). The fish population has an abundant pelagic fish community with relatively high numbers of sprat (42.6 %), herring (12.2 %) and sand smelt *Atherina presbyter* (4 %); these account annually for approximately 58 % of fish in Swansea Bay. The most abundant demersal species (whiting, bass *Dicentrarchus labrax*, pouting, lesser spotted dogfish *Scyliorhinus canicula* and poor cod) make up 14 % of the fish population; whilst benthic species (Goby species, plaice, grey gurnard, common sole, thornback ray *Raja clavata*, lesser sandeel *Ammodytes tobianus*, dab, sand goby *Pomatoschistus minutus*, hooknose *Agonus cataphractus*, solenette *Buglossidium luteum*, turbot and flounder) make up 24 % of the annual distribution of fish. The remaining 3 % of the annual fish population in Swansea Bay is composed of 37 species, each with an abundance of less than 0.1 %. The numbers of these fishes are inflated by the appearance of juveniles during the summer months.
- 9.4.1.6 The Swansea Bay fish community showed seasonal fluctuations relating to movements of species between feeding, spawning and nursery areas. During summer a variety of species moved into shallow inshore (intertidal) areas to feed, whilst during winter fish migrated further offshore into deeper (subtidal) waters. These changes are as a direct consequence of temperature, ontogenic development and prey availability.
- 9.4.1.7 Quarter 1 (winter 2013) catches in the intertidal zone were minimal as fish moved into deeper water to avoid potentially lethal or sub-optimal low temperatures (temperature $\pm$ S.D. = 5.2 ± 1.49 °C). Subtidal communities were dominated by cold-water species, notably adult gadoids, flatfish and gobies.
- 9.4.1.8 During Quarter 2 (spring 2013) warm waters (temperature $\pm$ S.D. = 12.8 ± 1.34 °C) led to intertidal sampling yielding greater numbers of fish than winter surveys. Abundance in intertidal zones was dominated by juveniles of several species (e.g. bass, turbot and herring); whilst the adult population was typically composed of sand smelt, lesser sandeel and mullet *Mugilidae* spp. Subtidal surveys were dominated by catches of adult plaice, sole, and elasmobranchs such as thornback rays.
- 9.4.1.9 The summer survey (2013, Quarter 3) yielded the greatest abundance of fish. This is to be expected as spring and summer spawners typically inflate fish numbers during this period. Abundance was dominated by pelagic fish such as sprat and herring. Similarly to spring surveys, bass were only captured in intertidal habitats. Large plaice were captured in deeper (subtidal) waters and juveniles were principally caught in shallow (intertidal) waters (Figure 9.5 and 9.6). A large number of juvenile gobies were found in Riley push-net samples in intertidal zones (Figure 9.6 (B)).

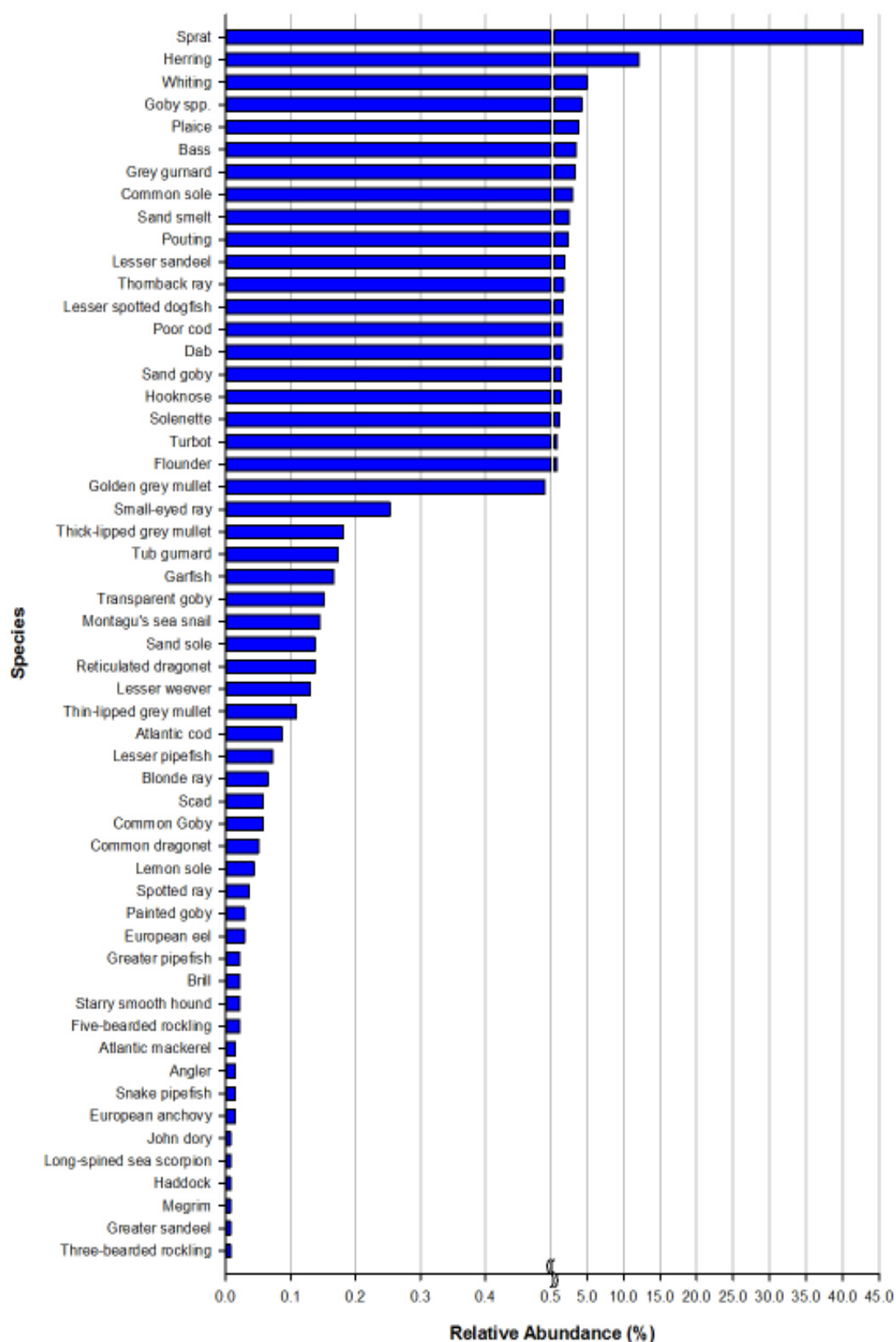


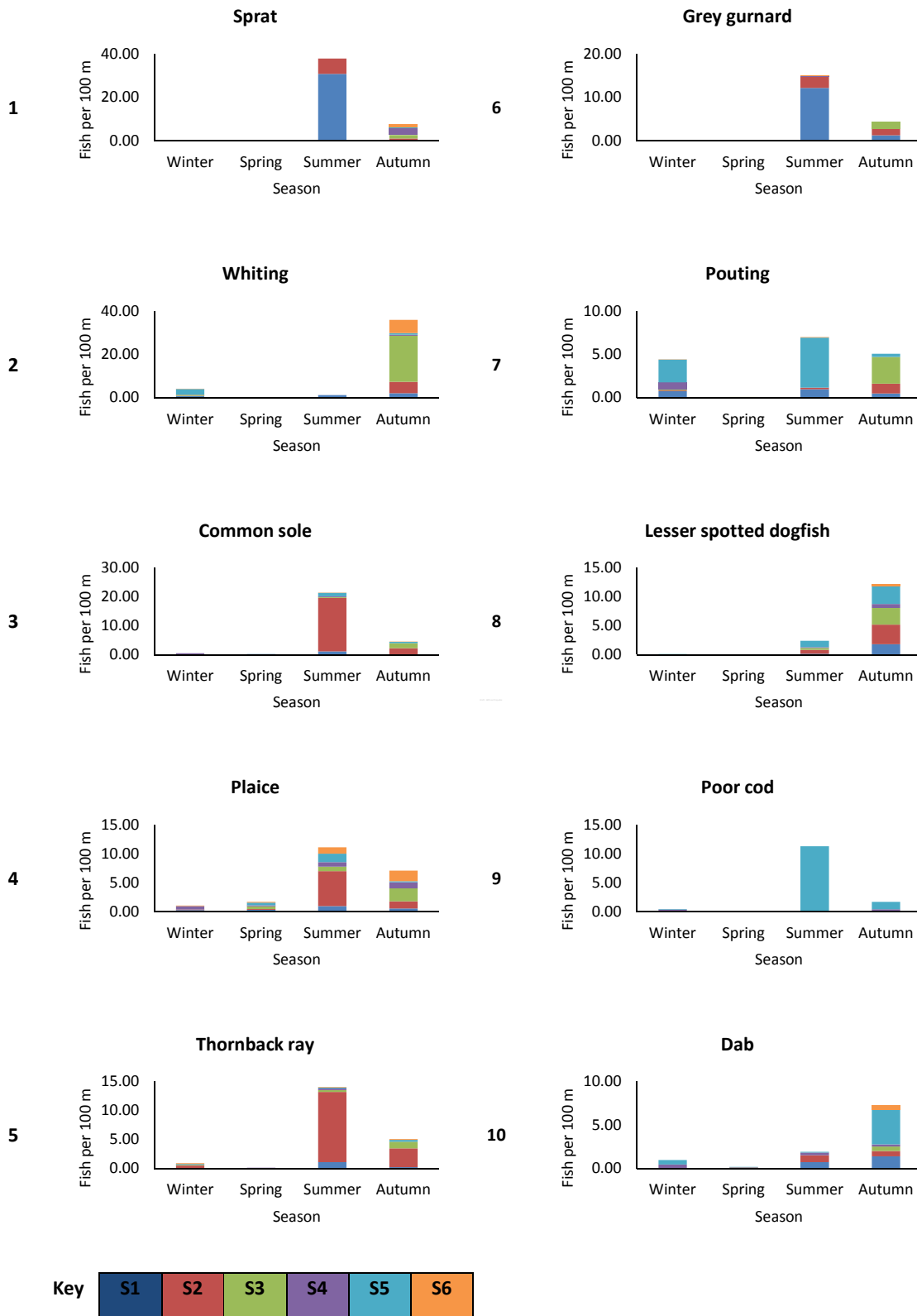
Figure 9.4 abundance of all fish species caught across the survey season. The axis has been broken at 0.5 % such that the left hand side represents values from 0 to 0.5 % and the right hand side represents values from 0.5 to 45 %.



- 9.4.1.10 In the autumn survey (2013, Quarter 4) the subtidal community was dominated by high numbers of gadoids, namely whiting, pouting and poor cod. Other species that showed an increase in the subtidal areas of the Bay compared with the summer survey included solenette, dab (increasing both in numbers and size), hooknose and lesser spotted dogfish. The fish population in intertidal areas was dominated by sprat (significantly less than in summer), sand smelt, turbot, golden grey mullet *Liza aurata* and common goby *Pomatoschistus microps*. The autumnal abundance of common goby is linked with the fact that by autumn specimens are developed enough to allow precise identification in the field.
- 9.4.1.11 The shellfish community within Swansea Bay includes molluscs, crustaceans, echinoderms and cephalopods. A total of 38 species were captured during the 4 Quarterly site-specific intertidal and subtidal surveys (see Appendix 9.2, Volume 3). The ten most frequently caught species across the 4 quarterly surveys were:
- i. Brittle Star *Ophiura ophiura* found in the winter, spring and autumn surveys;
 - ii. White furrow shell *Abra alba* found in the autumn survey with high abundance;
 - iii. Moon Jellyfish *Aurelia aurita* found in the summer survey with high abundance;
 - iv. Common starfish *Asterias rubens* found across all seasonal surveys;
 - v. Shrimp *Crangon spp.* found across all seasonal surveys;
 - vi. Prawn *Palaemon spp.* found across all seasonal surveys;
 - vii. Common cockle *Cerastoderma edule* found in the autumn survey with high abundance;
 - viii. Sea mouse *Aphrodita aculeata* found across all seasonal surveys;
 - ix. Common hermit crab *Pagurus bernhardus* found across all seasonal surveys;
 - x. Dog whelk *Nucella lapillus* found in the spring, summer and autumn surveys.



A





B

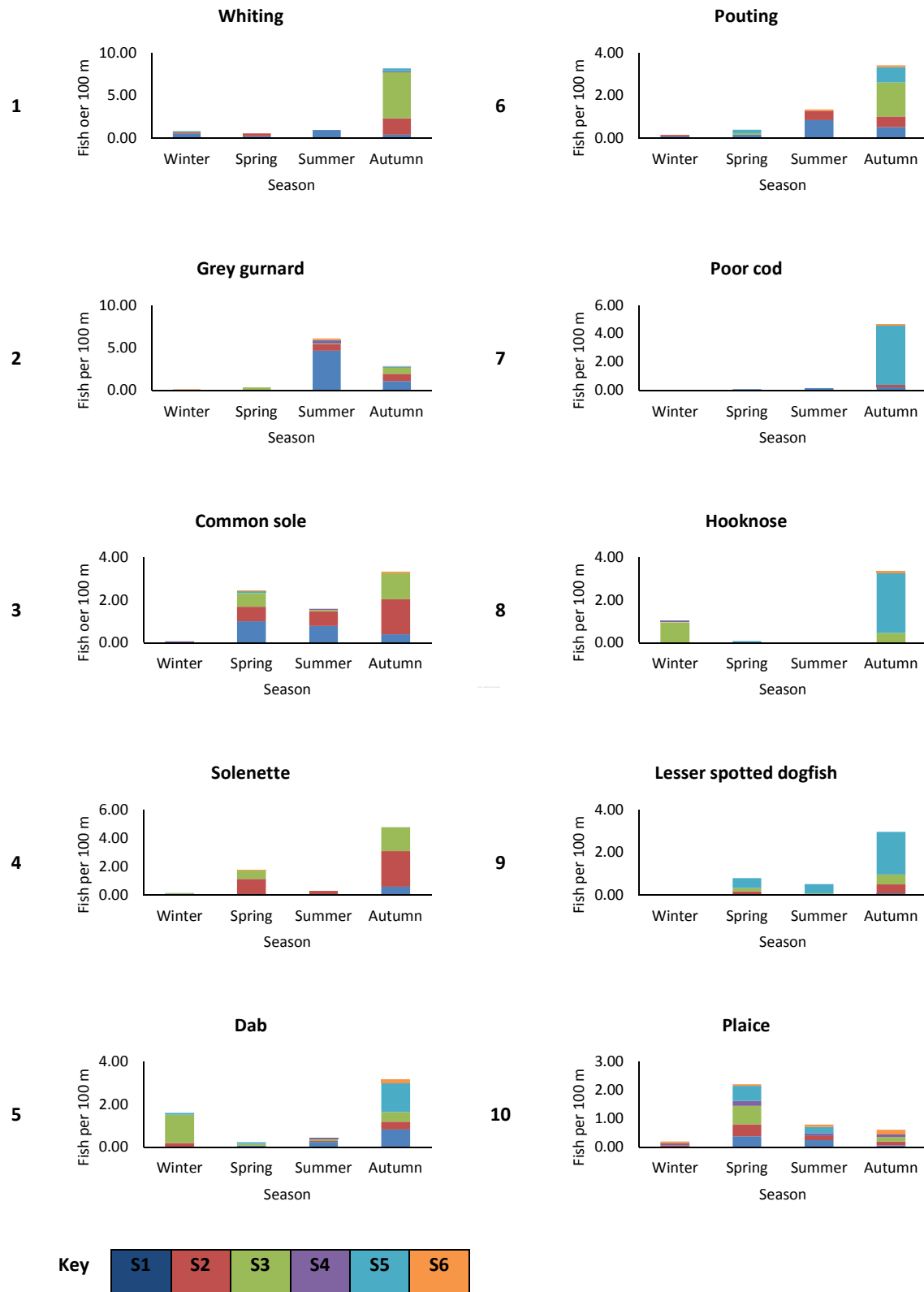
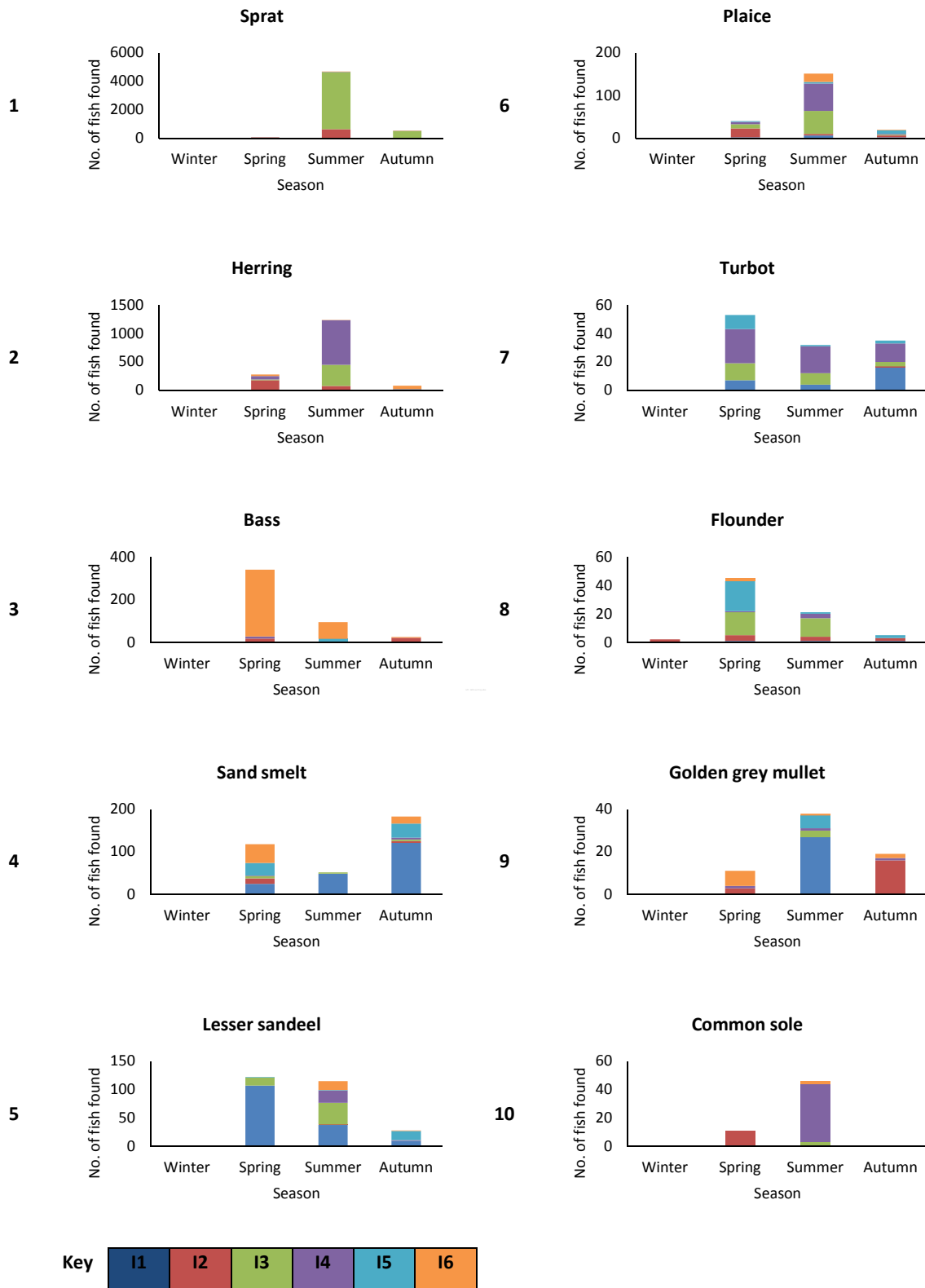


Figure 9.5 Abundance of the ten most common fish species per 100 m trawled in Swansea Bay; otter trawl surveys (A) and beam trawl surveys (B) are represented separately, whilst colours in stacked bars are representative of each site sampled.



A





B

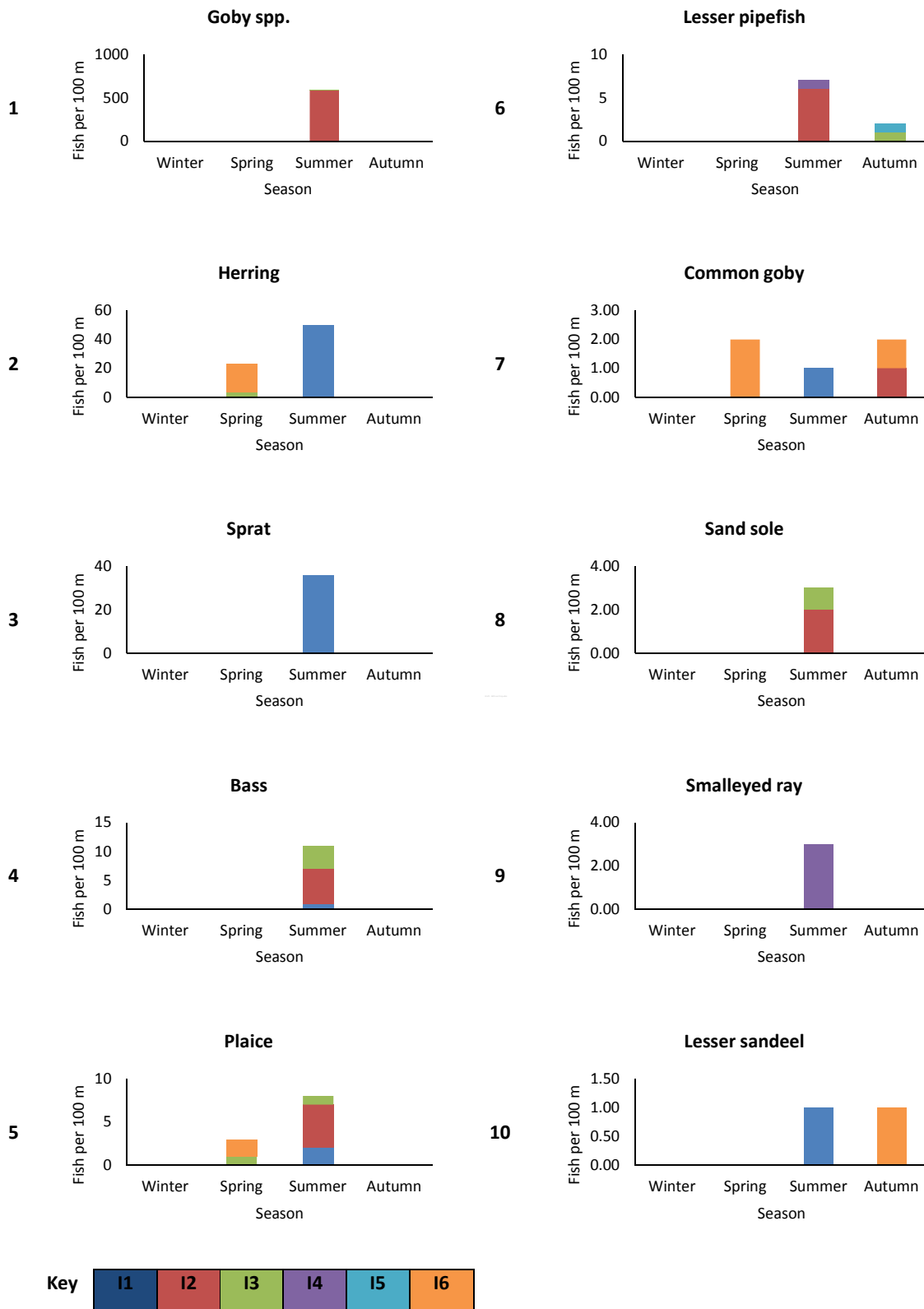
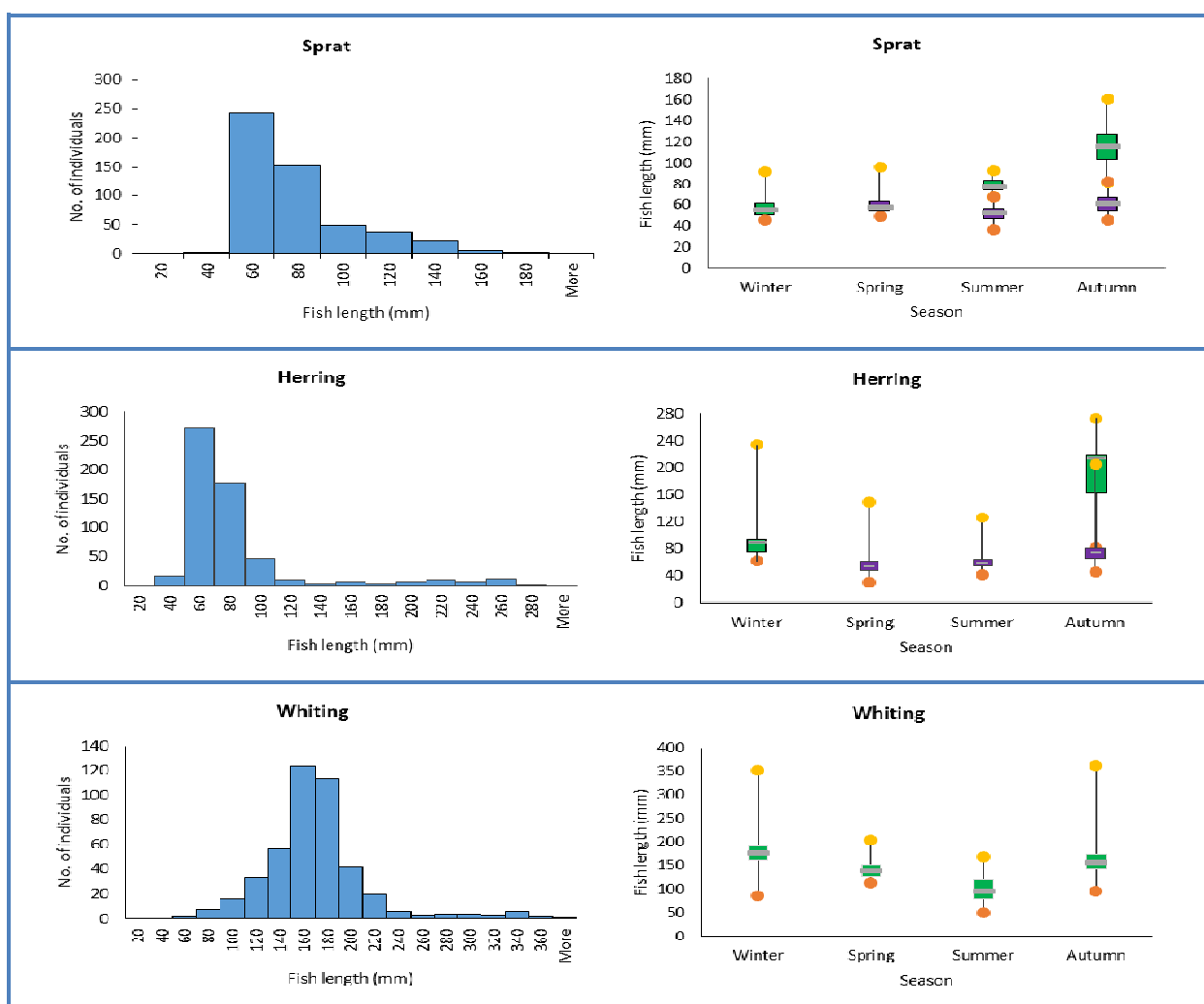
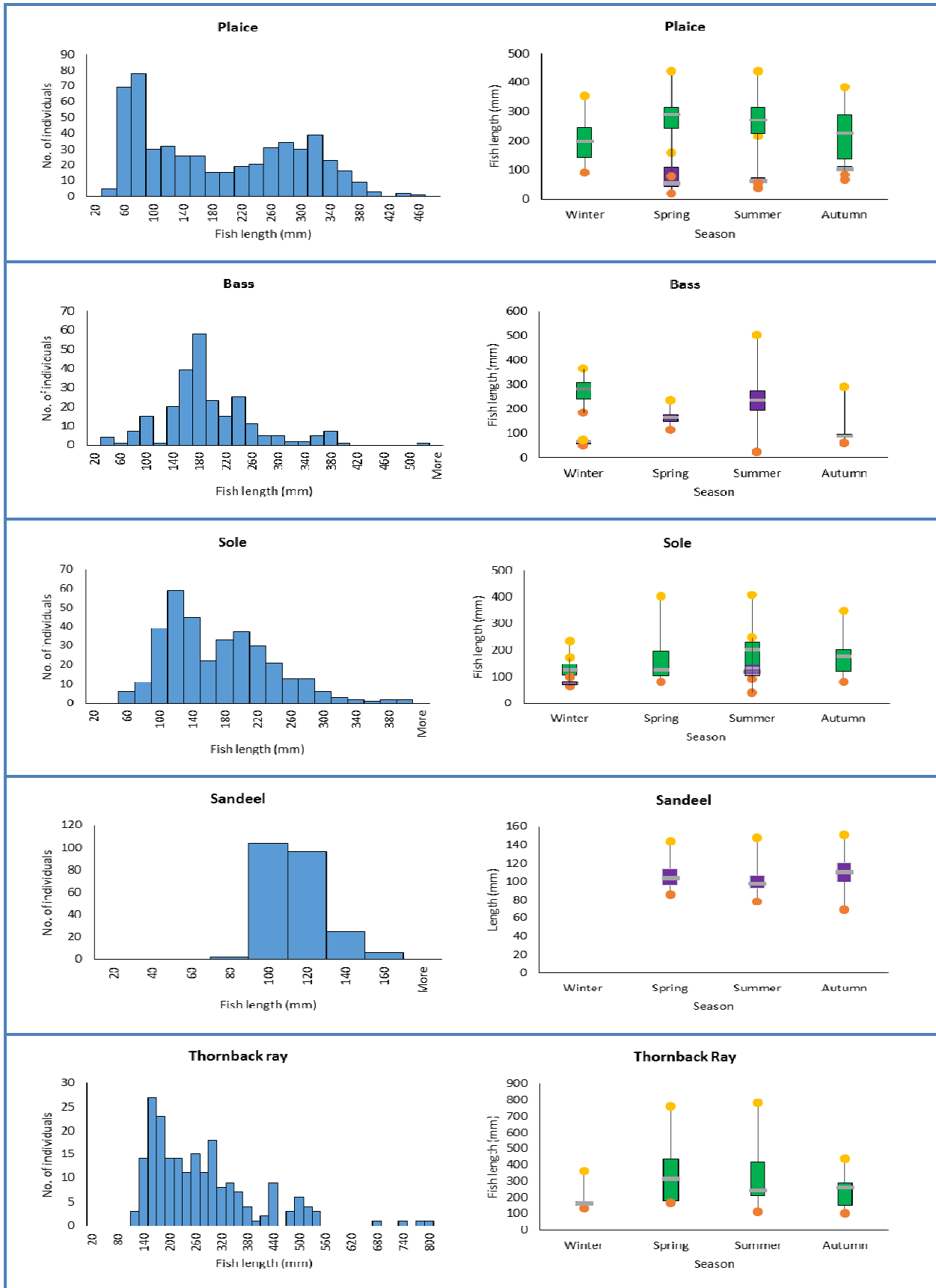


Figure 9.6 Abundance of the ten most common fish species during intertidal surveys for each of the techniques used; seine surveys (A) and Riley net surveys (B) are represented separately, whilst colours in stacked bars are representative of each site sampled.

9.4.2 Commercial fish and shellfish species

- 9.4.2.1 Several fish species of commercial and conservation importance are present in the Swansea Bay region, these include sole, plaice, bass and rays (e.g. thornback ray). Several of these commercially important species, as well as important prey species for larger fish, such as sandeel and sprat, have spawning and/or nursery grounds in the region. These species were selected for further analysis to investigate the size structure of the populations based on the findings of the 2013 surveys carried out as part of this Project (Figure 9.7).
- 9.4.2.2 Herring spawn early in the year. This is reflected by an intertidal abundance of juveniles during the spring survey, with a slight increase in size during the summer survey. Few adult herring were caught during the surveys: adults typically migrate offshore following spawning.
- 9.4.2.3 Flatfish juveniles, including plaice, sole and turbot, were abundant in intertidal areas during spring and summer. Whilst adult plaice and sole were caught in numbers during subtidal surveys, only a single adult turbot was caught. Typically, turbot move further offshore than plaice and sole.
- 9.4.2.4 Although turbot were found to be relatively abundant, they are not regarded as a commercially important species in the study area, most likely owing to the presence of juveniles but the lack of adults.





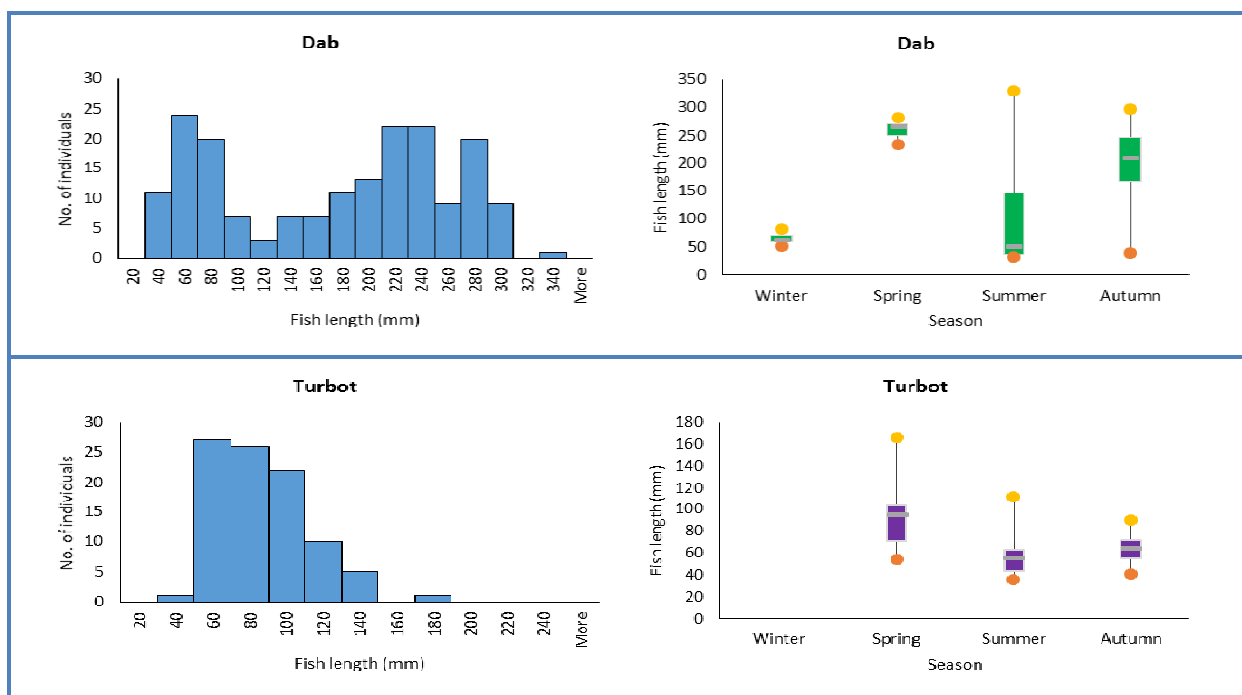


Figure 9.7 Length frequency histograms (both subtidal and intertidal) and box plots for several species caught during the 2013 surveys. Subtidal (green) and intertidal (purple) boxplots show significant variation in size.

- 9.4.2.5 Ten of the 38 species of macro-invertebrates identified from the quarterly surveys are recognised as having some commercial importance within Swansea Bay. Table 9.10 ranks these species by observations (recorded as log abundance). Cockle *Cerastoderma edule*, were found in high numbers during Quarter 4 (Autumn 2013), principally in intertidal areas around Blackpill. Whilst Brown crab *Cancer pagurus* and lobster were captured, their numbers were relatively low. The overall assemblage is consistent with information gathered through the desktop study and consultation.

Table 9.10 No. of observations of commercially important shellfish (recorded as log abundance) for all quarters and survey methods

Rank	Common name	Scientific name	Frequency class				Quarter present
			1 - 9	10 - 99	100 - 999	1000 +	
1	Cockle	<i>Cerastoderma edule</i>	1		2		Q4
2	Whelk	<i>Buccinum undatum</i>	8	2			Q1, Q2 & Q4
3	Crabs	<i>Cancer pagurus, Macropodia spp., Necora puber</i>	8				Q1 - Q4
4	Scallop	<i>Aequipecten opercularis, Chlamys varis</i>	2				Q4
4	Mussel	<i>Mytilus edulis</i>	2				Q1
4	Cuttlefish	<i>Sepia officinalis</i>	2				Q1
5	Lobster	<i>Homarus gammarus</i>	1				Q2

9.4.3 Migratory fish

- 9.4.3.1 There are four primary rivers draining into Swansea Bay: the Tawe, Neath, Afan and Kenfig; all of which hold populations of migratory fish, namely: European eel, Atlantic salmon, sea trout, river lamprey and sea lamprey. These fish utilise the Bay during their migrations to and from their spawning grounds. Twaite shad, though caught in the Bay, are not known to have any local spawning populations.

- 9.4.3.2 Four European eel were caught in the spring season surveys during intertidal seine netting (Appendix 9.2, Volume 3). No other migratory fishes were caught in intertidal or



subtidal surveys. It should be noted that, whilst these surveys were not designed specifically to sample migratory species, based on current evidence and consultations, they regularly occur within the study area. The majority of these species are protected through both UK and European legislation, and are therefore of high conservation value. Available information regarding migratory fish in Swansea is summarised below, and more detail is presented in Appendix 9.1 (Volume 3).

Atlantic salmon and sea trout

- 9.4.3.3 Evidence indicates that there are good salmon and sea trout populations within the rivers proximate to Swansea Bay (Environment Agency & CCW, 2009). Seasonal survey data shows the presence of juvenile salmon within all catchments with the exception of the R. Kenfig, whilst trout juveniles were caught within all rivers.
- 9.4.3.4 The River Tawe has the greatest numbers of salmon in the area, and numbers were steadily increasing from 1976 (Environment Agency, 2002b). The R. Neath has important salmon spawning grounds in its upper reaches, though most of the tributaries are used by non-migratory trout, as migration is obstructed by barriers. Salmon and sea trout also spawn in the R. Afan, though similarly to the R. Neath, evidence indicates connectivity issues, primarily as a result of over-abstraction and barriers.
- 9.4.3.5 A summary of rod catch data from the three rivers has been provided in section 9.4.8 (Table 9.41). Anecdotal accounts from the Environment Agency indicate that numbers of migratory fish over the last ten years have been decreasing (Evans, H., pers. comm., 15th February 2013). Inter-annual variation in salmon and trout numbers according to rod catch data is evident, however broad scale estimates of fish numbers seem to indicate fairly stable populations. It should be noted that populations across the UK are in decline (Environment Agency, 2011a).

European eel

- 9.4.3.6 Eel occur in all catchments flowing into the embayment. They migrate into rivers during spring and early summer as elvers, and remain there for several years. They spend most of their adult life in freshwater, before migrating out of estuaries, and back to the sea to spawn.
- 9.4.3.7 Availability of spawning habitat is not an issue in the case of eel, as reproduction occurs in the western-central Atlantic Ocean. It is, however, crucial that both connectivity during their migratory phase and habitat during their freshwater stay are good to ensure sufficient numbers of eel return to spawn.
- 9.4.3.8 Artificial barriers are prevalent on rivers in the Swansea Bay area, due to its industrial past (Defra, 2010). Measures to mitigate barriers, such as the construction of fish passes and river restoration will need to continue to further ensure the survival of this species.

River lamprey and sea lamprey

- 9.4.3.9 Lamprey spend their adult lives in the sea and return to rivers to spawn, typically river lamprey show fidelity to the estuaries of their natal rivers or coastal waters in their vicinity, whilst sea lamprey are known to undertake significant oceanic movements. There is no evidence to indicate the extent of lamprey spawning in any of the rivers flowing into Swansea Bay. Fishery surveys by NRW (previously Environment Agency) undertaken between 2001 to 2012 indicate that ammocoetes (juvenile lamprey) were found within all rivers at low densities, with exception of the R. Afan.



9.4.3.10 Spawning of river lamprey is observed by the Environment Agency on an annual basis on most rivers entering Swansea Bay (Evans, H., pers. comm., 15th February 2013). Sea lamprey have also been seen spawning in low numbers at the mouth of the River Neath (2 pairs seen in 2011).

9.4.3.11 Sporadic catches of lamprey have been reported on the Rivers Kenfig, Neath and Tawe in Environment Agency electric fishing data. Additional anecdotal evidence from recreational fishermen has shown presence of lamprey in the River Neath.

Allis and Twaite shad

9.4.3.12 No spawning populations of allis or twaite shad are found in Swansea bay. Only four rivers within the Severn catchment are known to support breeding populations of twaite shad: the Severn, the Wye, the Usk and the Tywi. Only two rivers are thought to hold breeding populations of allis shad: the River Usk and the Wye (Hillman et al., 2003).

9.4.3.13 Twaite shad are caught as by-catch within the Bay during spring (Bulley, D., pers. comm., 15th January 2013; Evans, H., pers. comm., 15th February 2013). They have also been captured by the Environment Agency at the mouth of the River Neath.

9.4.3.14 Anadromous fish populations, such as shad, are known to stray into areas other than their natal rivers, thereby providing a mechanism for colonisation of new catchments and gene flow between populations. It is possible that twaite shad could be moving into Swansea Bay from nearby populations.

9.4.4 Fish spawning and nursery areas

9.4.4.1 The Swansea Bay region provides a spawning and nursery area for a number of marine fish species, but many are offshore broadcast spawners, and do not lay eggs within the Bay.

9.4.4.2 A deep water area off Trevoze Head (Cornwall) and the outer Bristol Channel are thought to be important spawning grounds for many demersal and pelagic species including plaice, sole, lemon sole *Microstomus kitt*, dab, bass, whiting, cod *Gadus morhua*, sprat, sandeel, mackerel *Scomber scombrus*, horse mackerel *Trachurus trachurus*, hake *Merluccius merluccius*, turbot, and gurnard *Triglidae* spp (Ellis et al., 2012). It is likely that recruitment to nursery areas within Swansea Bay occurs in part from these sites.

9.4.4.3 Sandeel, an important keystone species, are substrate spawners, laying eggs on the seabed. Typically there is little movement of post-settled sandeel between spawning and nursery areas, it is assumed that the location in which adults are found is broadly similar to their spawning ground. The seasonal surveys undertaken as part of the project indicated relatively low numbers present in the study area as a whole and low numbers on Crymlyn Burrows (the intertidal area adjacent to the Lagoon (site i6)), most were found west of Mumbles head in the sandy bays of Caswell (179 of 290). During the surveys none were present at i6 in the winter and spring surveys, 16 were caught during the summer surveys and 2 during autumn. It should be assumed that any sandeel present within Swansea Bay would also spawn here.

9.4.4.4 During February and March herring spawn within Swansea Bay. Their spawning is concentrated in three locations across the Bay (see Figure 9.12).



- 9.4.4.5 Juvenile fish belonging to several species were caught during the 2013 surveys, these included: dab, turbot, plaice, flounder, bass, sprat, blonde ray *Raja brachyura*, small-eyed ray *Raja microocellata*, spotted ray *Raja montagui*, thornback ray, grey gurnard, golden grey mullet, poor cod, pouting and whiting. Sheltered conditions and abundance of food sources within Swansea Bay give rise to suitable habitats for juvenile fish.

9.5 Impacts on fish and shellfish ecology

9.5.1 Introduction

- 9.5.1.1 The following section describes the maximum potential adverse/favourable impacts on fish and shellfish species and their habitats as a result of the Project, as described in Chapter 4: Project Description. For decommissioning, works to remove turbines and sluice gates would not involve marine works and they would be removed in the dry by the gantry crane in a similar manner to routine maintenance works. However, potential changes to suspended sediments and deposition within the vicinity following removal of the turbines has been considered, as has the potential for noise during the actual removal works. Table 9.11 summarises the potential impacts on fish and shellfish.

Table 9.11 Potential impacts on fish and shellfish

Potential source	Potential impact	Potential effect
Construction phase		
Dredging, sand reclamation, formation and removal of temporary cofferdam.	Increases in suspended sediment and deposition.	I. Smother spawning grounds and benthic fauna. II. Impact on larval/juvenile fish. III. Injury and mortality. IV. Behavioural disturbance.
Piling, dredging, rock armour placement, increased vessel movements.	Increases in underwater noise and vibration.	I. Behavioural disturbance. II. Injury and mortality.
Construction lighting.	Increases in artificial light emissions.	I. Behavioural disturbance.
Construction of sea wall, temporary cofferdam and area for rock storage.	Habitat modification.	I. Loss/disturbance to spawning habitat. II. Loss/disturbance to foraging habitat. III. Gain of spawning habitat. IV. Gain of foraging habitat.
Dewatering of temporary cofferdam for turbine and sluice gate housing	Habitat loss due to dewatering of cofferdam.	I. Injury and mortality due to dewatering.
Dredging.	Entrainment from draghead.	I. Injury and mortality. II. Reduced fitness.
Operational phase		
Operation and presence of Tidal Lagoon.	Increases in suspended sediment and deposition.	I. Smother spawning grounds and benthic fauna. II. Impact on larval/juvenile fish. III. Injury and mortality. IV. Behavioural disturbance.
	Habitat fragmentation and isolation.	I. Delays to migration. II. Increased energetic costs. III. Fragmentation of migratory routes
	Habitat modification.	I. Loss/disturbance to spawning habitat. II. Loss/disturbance to foraging habitat. III. Gain of spawning habitat. IV. Gain of foraging habitat.
	Increased predation.	I. Injury and mortality. II. Reduced fitness.

Potential source	Potential impact	Potential effect
	Entrainment from draghead.	I. Injury and mortality. II. Reduced fitness.
Turbine operation.	Entrainment and injury from turbines.	I. Injury and mortality. II. Reduced fitness.
	Waterborne noise and vibration from the turbines.	I. Injury and mortality.
	Fluctuations in Lagoon water levels.	I. Behavioural disturbance. II. Injury and mortality.
Sluice operation.	Entrainment and injury from sluices	I. Injury and mortality. II. Reduced fitness.
Operational lighting.	Increases in light emissions.	I. Behavioural disturbance.
Changes in hydrological conditions and WWTW outfall.	Deterioration in water quality.	I. Behavioural disturbance. II. Increased mortality.
Insertion of power cables under River Neath.	Creation of EMFs.	I. Behavioural avoidance.
Recreational activities within the Tidal Lagoon.	Waterborne noise and vibration from recreational activities.	I. Behavioural disturbance.
Increase in recreational angling.	Increased pressure on fish populations as a result of recreational angling.	I. Increased mortality.
Decommissioning phase		
Removal of turbines and sluice gates.	Increases in suspended sediment and deposition.	I. Smother spawning grounds and benthic fauna. II. Impact on larval/juvenile fish. III. Injury and mortality. IV. Behavioural disturbance.
Removal of turbines and sluice gates and associated vessel movement.	Increases in underwater noise and vibration.	I. Behavioural disturbance. II. Injury and mortality.
Habitat modification.	Improved connectivity between the habitat within and outside the Lagoon.	I. Increased access to spawning grounds. II. Increased access to foraging grounds.
Cumulative		
Construction work associated with the Project occurring simultaneously to other Projects/activities.	Increases in suspended sediment and deposition.	I. Smother spawning grounds and benthic fauna. II. Impact on larval/juvenile fish. III. Injury and mortality. IV. Behavioural disturbance.
	Increases in underwater noise and vibration.	I. Behavioural disturbance. II. Injury and mortality.
	Habitat modification.	I. Loss/disturbance to spawning habitat. II. Loss/disturbance to foraging habitat. III. Gain of spawning habitat. IV. Gain of foraging habitat.
	Habitat fragmentation and isolation.	I. Delays to migration. II. Fragmentation of migratory routes.
	Increased predation.	I. Injury and mortality. II. Reduced fitness.
	Entrainment by turbines and water abstractions	I. Injury and mortality. II. Decreased fitness.

9.5.1.2 It is expected that the activities and impacts identified above will give rise to effects that are no greater than, or less than, those described in the following assessments. Additionally, all assessments below give severity estimates for unmitigated impacts; mitigation measures are then discussed (Section 9.4.6), and residual impacts are subsequently identified. Tables 9.28 to 9.38 provide a summary of the significance of potential environmental effects on fish and commercial shellfish ecology.



9.5.1.3 Sediment contaminant levels were found to be very low across the Project site. CEFAS guidance ascribes “action” levels depending on the severity of contamination to sediments to assess their suitability to dredging. All samples analysed (see Chapter 4. Project Description) were below CEFAS Action 2 levels and thus contaminant levels were below thresholds to be of any concern in respect of adverse/negative effect on fish populations in the Project area. As a result, the potential issue of re-suspension of contaminants, and their potential impact on fish and shellfish resources, has not been considered further.

9.5.1.4 The most likely source for pollutants is from installation vessels, and machinery operated on or adjacent to the water. It is proposed that published guidelines and best available practice (BAP) techniques are adhered to and that the draft Construction Environmental Management Plan (CEMP) (Chapter 4: Project Description) will be implemented. The risk of the release of pollutants from the Project is low and any consequent impact upon fish populations has not been considered further.

9.5.2 Construction phase effects

9.5.2.1 The construction phase is planned to run between 2015 and early 2019, with first power generated in summer 2018. The potential impacts on fish and shellfish, identified in Table 9.11, are discussed below. The effect of each impact is quantified for each of the VERs identified in Tables 9.28 to 9.38.

Increases in suspended sediment and sediment deposition

9.5.2.2 There is a potential for localised increases in suspended sediment (SS) concentration above background levels during the marine construction works. Activities contributing to potential increases will include: dredging of sand for use within Geotubes® or gravel mounds; disposal of any dredged material at the offshore disposal ground; dredging and formation of temporary cofferdam around turbine housing, and removal of the cofferdam when construction is complete. Offshore work is due to occur 24 hr/day, 7 day/week during the dredging season (April to October) weather permitting.

9.5.2.3 Dredging is known to have the potential to produce very high SS loads. A comprehensive review of dredging activity, associated sediment conditions and settling times has been carried out for San Francisco Bay, California (Griffin et al., 2009). The study concluded that, even when anthropogenic activity led to very high amounts of sediment, conditions reverted to normal background levels after 25 minutes. Suspended sediment loads of up to 20,000 mg l⁻¹ were only noted where muddy sediments were present.

9.5.2.4 Sediments within the bounds of the Project primarily comprise gravel and sand, with some smaller areas of fine sand (Chapter 6: Coastal Processes). As can be seen from the result of the coastal process modelling these particles typically settle quickly when disturbed.

9.5.2.5 Background concentrations of SS within the Severn Estuary are naturally extremely high, up to 3000 mg l⁻¹ (Henderson et al., 2012), owing to the high tidal range (up to 15 m) and dynamic nature of the estuary. Evidence indicates that the present ecosystem of the Severn Estuary is suppressed by the high and variable amounts of suspended sediment and the mobility of the bed (Kirby & Rance, 2010). Conditions in Swansea Bay are likely to be less extreme owing to the smaller tidal range (~ 8 m), this is confirmed by site-specific data which are summarised below, and reported in detail in (Chapter 6: Coastal Processes).



- 9.5.2.6 Suspended sediment concentrations were recorded at two moorings within the Bay for a four month period (February to May 2012); the mooring locations are shown in Chapter 6 (Coastal Processes, Sediment Transport and Contamination) Figure 6.7, Volume 2. Site 1 was located towards the shallow intertidal in a depth of around 1.4 m above CD (-3.6 mODN); i.e. within the breaker zone. Site 2 is more central to the Bay and in a depth of around 5 m below CD (-10 mODN). Mean near-bed suspended solid concentrations of approximately 113 mg l⁻¹ and 54 mg l⁻¹ were recorded at Sites 1 and 2 respectively. The generally higher concentrations at Site 1 are likely to be a function of the shallower environment within the surf zone which tends to retain concentrations above 50 mg l⁻¹. In comparison, concentrations at Site 2, located further offshore, tend to indicate lower concentrations during calmer periods, suggesting that some material may locally drop out of suspension.
- 9.5.2.7 Extensive modelling using DHI Mike 21 hydrodynamic and wave models has been undertaken and is presented in Chapter 6, Coastal Processes. The potential impacts of capital dredging associated with the construction of the west and east seawall were investigated. With respect to the western seawall, the model results indicate that the sediment plume disperses predominantly in a southerly direction through Swansea Bay and around Mumbles Head, and to a lesser extent, in a south-easterly direction towards the centre of Swansea Bay. In the case of the plume that passes around Mumbles Head, the maximum SS concentrations at this extent are less than 10 mg l⁻¹ above background concentrations. The modelling also shows that increased SS only exceeds 60 mg l⁻¹ within Swansea Bay along an approximate 500 to 1,500 m track extending from the dredge/fill location towards Mumbles Head, and also towards the Swansea shoreline.
- 9.5.2.8 For the eastern seawall construction increases in SS above 100 mg l⁻¹ are identified within the Neath Channel, across Baglan Bay, along the Crymlyn Burrows frontage and within the shallow subtidal region to the east of the Swansea Channel (i.e. largely within the footprint of the proposed Lagoon). At the entrance to the Neath, peak concentrations reach around 115 mg l⁻¹ during the works, falling to back background concentrations following cessation of activities. This compares with results from the recent metocean survey which indicated that that mean background near-bed SS are in the vicinity of 113 mg l⁻¹ and 54 mg l⁻¹ across the intertidal and shallow subtidal areas of Swansea Bay, respectively (Chapter 6, Coastal Processes), with peak concentrations in the order of 460 to 570 mg l⁻¹.
- 9.5.2.9 Modelling of sedimentation patterns (settling) during the construction of the western and eastern seawall indicates that localised sediment increases of 4 mm will occur in the immediate vicinity of works, with changes elsewhere across Swansea Bay and beyond Mumbles Head being indiscernible from background variation (Figure 6.19; for more information see Chapter 6: Coastal Processes, Sediment Transport and Contamination). The sediments deposited during construction are predicted to be rapidly eroded over a single tide following cessation of the works.
- 9.5.2.10 Shellfish and fish are known to be sensitive to increases in SS concentrations, both directly, through physiological and behavioural disruption, and indirectly, through habitat modification. Higher levels of suspended solids can impair foraging, increase mortality, affect growth, reproduction and survival at all trophic levels. However, there is also evidence to indicate that high SS loads and associated turbidities found in natural ecosystems (e.g. Bristol Channel) can create feeding opportunities for some species, especially demersal fish (Henley et al., 2000).



- 9.5.2.11 Limited published information is available on the tolerances of egg and juvenile marine fish to sediment, thus there is some uncertainty in the assessment on these life stages. For adult fish, more information is available, though in many cases studies on non-indigenous surrogates have to be used due to a lack of work on native fish.
- 9.5.2.12 Table 9.12 identifies the typical residence and spawning periods of key species that are found within the wider study area and the Bay, on which the planned dredging periods have been superimposed. Of the species shown only herring are known to spawn in the Lagoon footprint, whilst sandeel are thought to spawn within the wider Bay area. Other species are also resident within the wider study area. However, some species such as plaice, do not spawn within the Bay, and as their spawning period is not within the dredging work period (April to October), sedimentation impacts will not affect the eggs of these species.
- 9.5.2.13 Fish eggs and larvae tend to be more sensitive to increases in SS than older life-stages. Fine sediment settling on eggs can reduce oxygen-transfer, potentially causing asphyxia and retarded development or death.
- 9.5.2.14 Pelagic fish eggs have the potential to be negatively affected by SS. Their survival is reliant on them remaining suspended in the water column. Fine SS can stick to eggs and increase their density, leading to them settling on the bottom (Sørensen & Skyt, 2003). This has the potential to increase their predation by demersal fish, as well as lead to oxygen deficiency. Studies have shown that at SS concentrations of 5 mg l⁻¹ cod eggs can sink to the bottom in 96 hours. There are many factors affecting the way suspended sediment interacts with eggs, including: particle size, turbulence and sediment source.
- 9.5.2.15 Eggs of the North American striped bass *Morone saxatilis*, a species with similar morphological characteristics to European bass, have been shown to successfully hatch at sediment levels of up to 1000 mg l⁻¹ with no significant effects on hatching success. However, it is unlikely that eggs of bass, which have not been found to spawn within the Bay, will drift in from offshore spawning grounds (see Appendix 9.1, Volume 3).
- 9.5.2.16 Blueback herring *Alosa aestivalis* are an American species belong to the Clupeid family, and are comparable in morphology to herring and shad (*Alosa alosa* and *Alosa fallax*). Studies on this species indicate that when subjected to high densities of SS (up to 1000 mg l⁻¹) hatching success is not significantly affected. Kiorbe et al. (1981) showed that eggs of herring subjected to constant concentrations of moderately high SS (500 mg l⁻¹) were not affected; whilst Griffin et al. (2009) noted no discernible effect from SS concentrations of up to 400 mg l⁻¹; other work has shown even higher tolerances to sediment, in the region of 7000 mg l⁻¹ (Clarke & Wilber, 2000).

Table 9.12 Possible residency (green) and spawning periods (red) of key fish and shellfish species that are found within Swansea Bay; orange area indicates the period in which dredging and piling activity would take place. Note: evidence for spawning within the Bay has only been found for herring and thornback ray.

		J	F	M	A	M	J	J	A	S	O	N	D	Life stage
Non-diadromous fish														RA KE SM G/E A RA KE SM
Common name	Scientific name													
Herring	<i>Clupea harengus</i>													
Lesser sand eel	<i>Ammodytes tobianus</i>													
Sole	<i>Solea solea</i>													
Sprat	<i>Sprattus sprattus</i>													
Thornback ray	<i>Raja clavata</i>													
Diadromous fish														
Allis shad	<i>Alosa alosa</i>													
Atlantic salmon	<i>Salmo salar</i>													
European eel	<i>Anguilla anguilla</i>													
River lamprey	<i>Lampetra fluviatilis</i>													
Sea trout	<i>Salmo trutta</i>													
Twaite shad	<i>Alosa fallax</i>													
Shellfish														
Mytilus edulis	<i>Common mussel</i>													
Native oyster	<i>Ostrea edulis</i>													

Note: RA=returning adult; KE=kelt; SM=smolt; G/E=glass eel or elver; A=Adult

9.5.2.17 Juveniles of many fish species are visual foragers. Larval fish such as anchovy *Engraulis encrasicolus*, plaice, sole, turbot and cod use vision as one of their primary feeding senses, and can only sight prey at a distance greater than 2 mm (Bone & Moore, 2008). Johnston & Wildish (1982) indicated that SS levels above 20 mg l⁻¹ can in some cases inhibit the foraging success of juvenile herring. However, effects are limited to very small larvae. Conversely, Boehelert & Morgan (1985) indicate that high suspended sediment (between 500 and 1000 mg l⁻¹) loads can actually increase incidence and intensity of feeding in juvenile herring. Any reduction in visibility as a result of the elevated SS levels in the Bay is likely to be short-term and localised, so any widespread or sustained effect on feeding success of larval fish is highly unlikely. In any case, natural background levels in Swansea Bay are typically above the 20 mg l⁻¹ threshold suggested by Johnston & Wildish (1982).

9.5.2.18 The spawning and early lifestages of shads (*Alosa alosa* and *Alosa fallax*), lampreys (sea lamprey and river lamprey, sea trout and Atlantic salmon occur only in rivers, and hence will not be directly affected by the sediment released in the Bay. Similarly, the spawning of the catadromous European eel occurs outside of the Bristol Channel and will not be affected by the predicted sediment releases.



- 9.5.2.19 Sediment levels can also impact adult fish. Lethal impacts typically occur at concentrations in the grams per litre range (g l^{-1}). At lower levels avoidance responses can be expected for certain species of fish (Sørensen & Skyt, 2003).
- 9.5.2.20 Evidence indicates that re-suspension of sediments associated with fishing activity (e.g. trawling) can be positive for flatfish, as benthic food items become exposed (Gibson, 2005). English sole *Perophrys velutus*, a fish species in the same family as plaice, was tested in SS concentrations of $70,000 \text{ mg l}^{-1}$ (Peddicord et al., 1975). Results indicated no mortalities even at these extremely high levels. Adult cod have been shown to survive exposure to 550 mg l^{-1} of SS for periods of up to ten days with no mortalities (Humborstad et al., 2006).
- 9.5.2.21 Avoidance behaviour by adult herring is known to occur at relatively low SS levels, though their response seems to be dependent on the nature of the sediment (e.g. $19 \pm 5 \text{ mg l}^{-1}$ for fine sediment, and $35 \pm 5 \text{ mg l}^{-1}$ for coarser sediment) (Wildish & Wilson, 1977). Surveys carried out at power station screening facilities within the Severn Estuary indicate significant numbers of herring in areas where SS levels are known to be high (Claridge et al., 1986), this suggests that their susceptibility to sediment may vary.
- 9.5.2.22 Atlantic salmon are found in the Severn Estuary in areas which can contain several thousand mg l^{-1} of SS (Gibson, 1933), as are juvenile (glass eel) and adult (silver) European eel, which are well adapted to high concentrations of suspended solids (Maitland & Campbell, 1992). Both species are often found in estuaries with very high concentrations of sediment and are known for migrating in periods of notable turbidity, whilst avoiding movements in clearer conditions (Alabaster & Lloyd, 1982).
- 9.5.2.23 Filter-feeding shellfish species, especially bivalves such as native oysters *Ostrea edulis*, Pacific oysters *Crassostrea gigas* and edible mussels *Mytilus edulis* could be impacted by the increases in SS. Evidence indicates that native oysters begin to be impacted, primarily through alterations to feeding patterns, at levels above 5 mg l^{-1} (Hutchinson & Hawkins, 1992). Filter-feeding bivalves exposed to higher sediment loads use more energy in expelling inorganic sediment which can retard growth and development. High sediment levels would need to be maintained continuously for a large part of the growth season for any effect to become significant (Robertson et al., 2006; Wood and Armitage, 1997; Kerr, 1995).
- 9.5.2.24 Widdows et al. (1979) found that the effect of inorganic silt in suspension was to limit, by 'dilution', the amount of food material ingested rather than to reduce the amount of material filtered by the mussel. Clearance rate declined with increasing suspended solids and resulted in minimal feeding and pumping activity at approximately 220, 260 and 330 mg l^{-1} for mussels 30, 50 and 70 mm in length, respectively. Thus, mussels are well adapted to living in turbid environments and can function efficiently in all but the highest SS concentrations.
- 9.5.2.25 Gastropods found in the Swansea Bay area, such as common whelk, are more tolerant, and are unlikely to be harmed by increased SS levels.
- 9.5.2.26 The mobilisation of bed sediments may lead to nutrients being released in the water column. This could potentially induce short-term phytoplankton blooms/localised eutrophication. Given the limited area over which SS levels will be increased during construction (see Chapter 6: Coastal Processes), and the strong tidal flushing of Swansea Bay, it is thought that any nutrients released would rapidly dilute and dissipate before



giving rise to blooms, this issue is further discussed in Chapter 7 Water Quality Assessment.

- 9.5.2.27 Navigation of diadromous fish into the local rivers Tawe and Neath, and into the more distant Special Areas for Conservation (SAC) rivers, the Wye and Usk, is not expected to be disturbed by such increased SS levels as may be associated with Lagoon construction. The Bristol Channel and Severn Estuary have naturally exceptionally SS high levels and diadromous fish species successfully migrate through such conditions as a matter of course. Migratory salmonid fish have been shown to use olfactory cues associated with water chemistry for coastal water navigation (see paragraph 9.5.3.31). The localised nature of any dredging plumes would give ample opportunity for fish to circumvent them.
- 9.5.2.28 Mortality or injury as a result of the sediment released during construction is very unlikely: first, due to the high concentrations of background sediment in the area; and secondly, due to the ability of mobile species to escape from the affected zones. Sessile stages of shellfish which are unable to take avoiding action will potentially be more vulnerable, but any effects would be limited in extent to areas in the immediate vicinity of the construction work.
- 9.5.2.29 Best practice for minimising impacts associated with suspended solids is discussed in Section 9.4.6.

Increases in underwater noise and vibration

- 9.5.2.30 The primary activities leading to increased underwater noise and vibration during the construction phase of the Project will be insertion of sheet piling, dredging and placement of rock armour. These activities are expected to be intermittent over the 39 month construction period between April and October. Increases in general construction activity, such as excavation and vessel movement will also contribute to the overall level of subsea noise and vibration within the area.
- 9.5.2.31 The impact of noise on fish can be subdivided into three distinct categories:
 - i. lethal effects;
 - ii. sub-lethal effects; and
 - iii. behavioural avoidance.
- 9.5.2.32 In terms of potential impacts in the immediate vicinity of impact piling, fish may be killed, stunned or injured, although noise levels are too low for such effects when vibro-piling is used (Figure 9.10). Again with impact piling or other noisy activities, at a longer range, fish may be put off feeding or avoid noisy areas, with the potential to disturb optimal migration routes, obstruct migration, disturb group coherence or mask orientation cues.
- 9.5.2.33 Severe injury is only likely to occur within the close proximity of a sound source, for instance, impact piling when at full force. Permanent threshold shift (PTS), termed as a non-reversible impairment of hearing, is generally caused by the destruction of the hearing apparatus as a result of overstimulation in extreme cases.
- 9.5.2.34 Several metrics are used to assess subsea vibration and noise. Exposure is typically expressed in peak or RMS (root-mean-square) sound pressure level (SPL) (peak-to-peak or average unweighted sound over a given measurement period) and cumulative sound exposure level (SEL) (the sum of acoustic energy over a given measurement period)



(Nedwell et al., 2007). Underwater noise levels are generally expressed in terms of decibels relative to a reference pressure of one micro Pascal (dB re 1 μ Pa).

- 9.5.2.35 Fish perceive underwater vibration through two primary mechanosensory organs. One is the lateral line system, sensitive only to low frequencies (typically below 150 Hz), usually only serving to detect vibrations in close proximity to a source (Wahlberg & Westerberg, 2005). The second is the inner ear, which is sensitive to sounds over a wider frequency range and from greater distances, and is more relevant when determining how fish behaviour is affected by underwater noise from construction activities. The mechanism of how sound is transmitted to the inner ear is dependent on the presence or absence of a swim bladder. The swim bladder acts as a pressure-to-motion transducer, hence fish with gas-filled bladders can perceive both particle motion and sound pressure, whilst fish with no swim bladder or a deflated or vestigial swim bladder can only perceive particle motion. The mechanical coupling of the swim bladder to the ear is also an important characteristic in establishing the sensitivity of fish to noise (Vella et al., 2001).
- 9.5.2.36 On the basis of the swim bladder coupling to the inner ear, some fish, such as herring, with good acoustic coupling are described as “hearing specialists” (having sensitivities as low as 50 dB re 1 μ Pa), whilst others, such as adult flatfish which have no functional swimbladder, are less sensitive to sound and are considered “hearing generalists” (typically sensing sounds > 110 dB re 1 μ Pa). The frequency ranges of sounds audible to fish vary according to species. Some fish, such as eel, respond to infrasound frequencies as low 12 Hz, though generally, the frequency range at which most fish can hear falls between 60 and 3000 Hz, i.e. within the range audible to humans.
- 9.5.2.37 Ambient noise levels for open coastal waters are typically between 60 to 100 dB re 1 μ Pa over the range 10 to 2000 Hz (Vella et al., 2001). Previous studies in Swansea Bay have shown background noise levels during calm conditions ranging from 90s dB (LW) to 120 dB (Willis et al., 2010). During recent survey work in April 2013 the ambient noise levels measured at various locations around the Lagoon were approximately 110 - 120 dB (Chapter 19: Noise and Vibration).
- 9.5.2.38 Fish eggs and larvae can be affected by high SPLs. Trials using seismic exploration airguns indicate significant effects, including mortality, in eggs of cod, saithe *Pollachius virens* and herring when exposed to sound (peak pressure levels of 220 to 242 dB re 1 μ Pa²) but these levels were restricted to 5 m from the source (Booman et al., 1996). Response varied for the species assessed depending on life stage: at yolk sac stage, cod and herring were not affected, whilst significant effects were found in turbot eggs (including mortality). Deleterious effects do seem to be species-specific; for instance further evidence indicates that sole larvae do not seem to be affected by piling noise equal to 206 dB re 1 μ Pa² (Bolle et al., 2011). The levels which are expected in the present construction work are projected to be lower for the vibro-piling works, which is expected to be the main piling technique used. Deleterious impacts on eggs are only likely to occur in the immediate vicinity of the piling operations (i.e. < 5m).
- 9.5.2.39 No European-wide criteria are available regarding the maximum threshold levels at which undersea noise proves to be damaging to fish. Regulatory bodies in the United States have defined the level at which the onset of physical injury for fish > 2 g to be (Stadler & Woodbury, 2009):
- I. when the peak SPL exceeds 206 dB re 1 μ Pa; and
 - II. when the SEL accumulated over 24 h exceeds 187 dB (re 1 μ Pa² s⁻¹).

9.5.2.40 The reference levels given above offer guideline criteria for reducing the risk of noise-related fish injury, and would only be likely to occur in proximity of the source. Other than for fish eggs that are attached to the substrate (e.g. herring) or in the plankton close to the piling location, fish would be able to swim away from the noise source, provided that soft-start procedures were employed if impact piling were being used.

9.5.2.41 Figure 9.8 shows a number of audiograms (showing audible thresholds) for species which are found in the vicinity of Swansea Bay. Owing to the fact that no audiograms were found for native species of ray, a comparable surrogate from the North Western Atlantic has been included. In these audiograms, the lowermost point for the given species indicates the hearing threshold at that particular frequency, so that herring (a hearing specialist) are the most sensitive to sound and *Raja* spp. (a hearing generalist) the least sensitive. Cod are also sensitive but over a narrower frequency band than herring. Demersal fish as a whole have relatively poor hearing, with typical thresholds falling between 90 and 110 dB; this includes flounder, dab, plaice, turbot, sandeel and gobies (Sorensen et al., 2000).

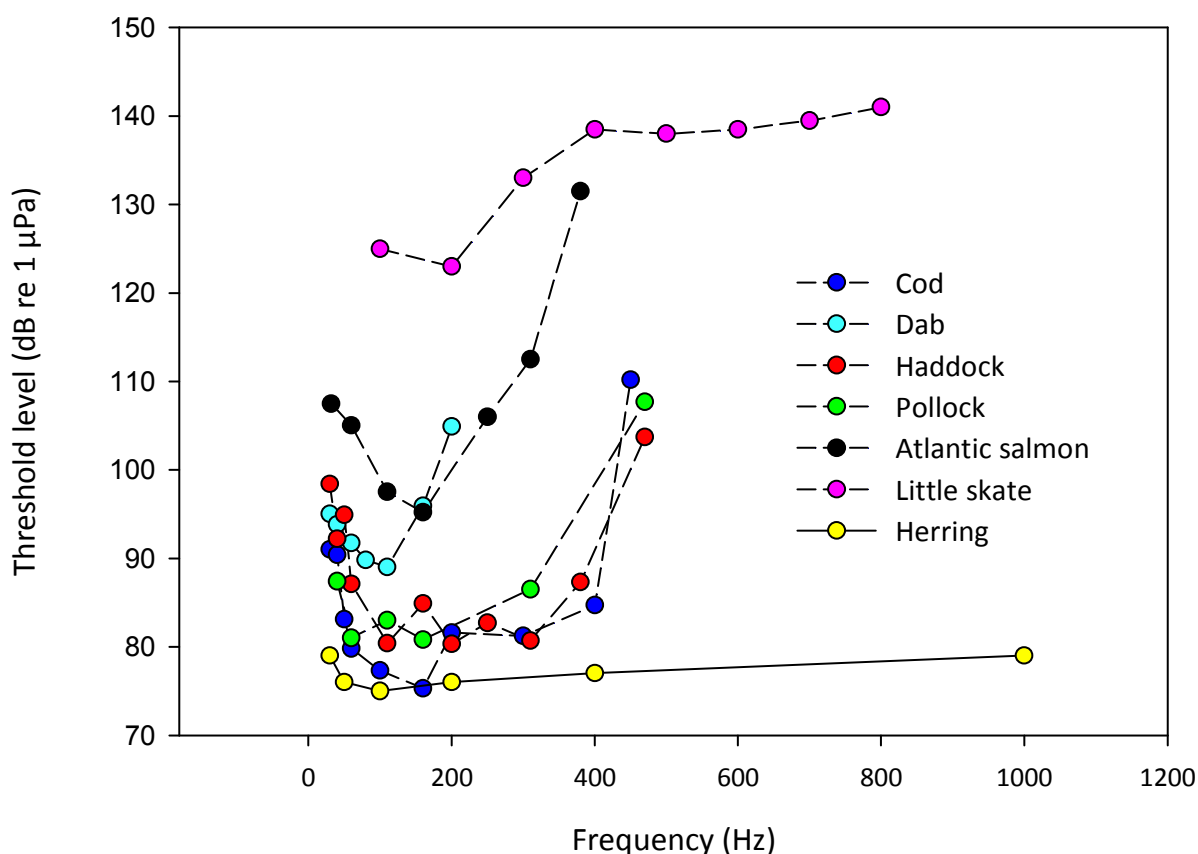


Figure 9.8 Audiograms of cod (Offut, 1974); dab (Hawkins & Myrberg, 1983); haddock *Melanogrammus aeglefinus* (Fay, 1988); pollock *Pollachius pollachius* (Fay, 1988); Atlantic salmon (Hawkins & Johnstone, 1978) and little skate (Casper et al., 2003).

9.5.2.42 Avoidance of underwater noise has been investigated for a few species of flatfish. In some cases their response entails burial (e.g. flounder) (Nedwell, 2008). This could potentially increase the likelihood of injury to species adopting this kind of behaviour, though this would have to occur in the immediate proximity to a source.

9.5.2.43 Rays do not have a swim bladder and have a low sensitivity to noise (Drabble, 2012). No published data is available for species of ray which are found in Swansea Bay. However,

studies carried out on the closely related little ray *Raja erinacea*, show a threshold level of 122 dB re 1 μ Pa at 200 Hz (Casper et al., 2003).

- 9.5.2.44 Evidence for the hearing capabilities of lamprey is scarce, and to date there no audiograms appear to have been published for this primitive family of fishes. Work suggests that they can respond to frequencies between 20 and 100 Hz (Lenhardt & Sismour, 1995). However, given the lack of specialist structures to hear sound they should be considered hearing generalists with very low hearing sensitivity. It is thought they may be able to detect infrasound (ABPmer, 2013).
- 9.5.2.45 The clupeid family of fishes, which includes herring, sprat and the shads (*Alosa alosa* and *Alosa fallax*), are hearing specialists, with high sensitivity to noise. Shad are known to show strong avoidance behaviour when subjected to ultrasound (202 dB re 1 μ Pa at 200 kHz). Such high frequencies will not be emitted by any of the construction work for the Project.
- 9.5.2.46 Evidence for eel hearing sensitivity is mixed. According to Tesch (Tesch, F W (Thorpe, 2003) eel show some avoidance reaction to frequencies of 2500 Hz, and even weak responses to frequencies as high as 9000 Hz; additionally, they have been shown to display escape reactions to sounds at 50Hz whilst becoming restive at 400Hz. (Tesch, F W (Thorpe ed., 2003)). In other studies, eel have shown avoidance reactions to infrasound frequencies of less than 20 Hz but have failed to react to high sound pressure levels (> 180 dB re 1 μ Pa) in the 50-2000 Hz range, though this was possibly due to a swim bladder infection (Environment Agency, 2011c). Eels can be classified as hearing generalists with poor hearing sensitivity.
- 9.5.2.47 Little published evidence exists on sandeel hearing sensitivity. Their lack of a swim bladder implies that they have a fairly high tolerance to sound emissions. Studies carried out on Pacific sand lance *Ammodytes personatus* support this view, showing the species as having an auditory threshold of 120 dB at 128 to 362 Hz (Suga et al., 2005).
- 9.5.2.48 A separate assessment of existing underwater background noise levels in Swansea Bay associated with hydraulic conditions, shipping movements, etc., and of noise levels that are likely to arise from the Project construction phase has been undertaken (Chapter 19, Noise and Vibration). Acoustic propagation conditions are limited by the shallow water depths in the Bay, and this, together with high ambient subsea noise levels, will limit the extent to which operations and construction activities are likely to influence fish.
- 9.5.2.49 Sound decay modelling has been undertaken to estimate the likely distances from construction noise at which avoidance by selected fish species will occur. The threshold SPL at which 50 % of fish can be expected to show avoidance behaviour is taken as +75 dB above the species' hearing threshold, with strong avoidance by most species occurring at +90 dB (Nedwell et al., 2007). Fish audiograms have been used in conjunction with piling emission spectra taken from literature to identify the range at which piling will elicit a behavioural response (Norro et al., 2010; De Jong & Ainslie, 2008). Figure 9.9 to Figure 9.11 show the predicted ranges at which dredging, vibratory piling and impact piling will have an effect on key species, results are also tabulated in Table 9.13. These were calculated using the following equation:

$$\frac{\text{Log R} = \text{SL-SPL}}{\text{Ng}}$$

Equation 1

Where R is the range from source (m) to which the avoidance level extends, SL is the noise source level in dB above the species' hearing threshold, SPL is the avoidance threshold (75 or 90 dB above hearing threshold), and Ng is the transmission loss coefficient. The source level of the noise above hearing threshold for each species was determined using audiograms such as shown in Figure 9.8, as described by Nedwell et al. (2007).

- 9.5.2.50 The value of Ng used for this application was 20, implying spherical spreading of the sound. The main concern with regard to fish was the potential for noise to exclude marine fish from critical nearshore and intertidal habitats and to deter migratory fish from entering or leaving the Tawe and Neath river mouths. In these cases the sound propagation is into shallowing areas of the Bay, where attenuation is more severe. A transmission loss of $Ng=20$ is considered a conservative value for this application, compared for example with shallowing water cases reviewed by Nedwell and Edwards (2004) where more extreme transmission loss values of up to $Ng=25$ were found.
- 9.5.2.51 Pile driving activity will take place only to construct the turbine house, while dredging and seawall construction activity will extend inside and around the full perimeter of the Lagoon. Table 9.13 sets out the ranges from the construction activity source to which levels above 75 and 90dB above hearing threshold respectively will extend. Levels beyond these ranges are deemed unlikely to cause significant fish exclusion from habitats.

Table 9.13 Modelled ranges (m) at which a number of species will be impacted by piling. Note: some sounds may fall outside of response range (ORR) for particular species.

Species	dB above hearing threshold	Behavioural response range (m)		
		Dredging	Vibro-piling	Impact piling
Cod	75	31	79	1778
	90	6	14	316
Hearing generalist	75	10	17	446
	90	1.78	3	79
Herring	75	56	141	3162
	90	10	25	562
Eel/lamprey	75	3	6	117
	90	ORR	ORR	31
Salmon/ trout	75	3	5	177
	90	ORR	ORR	31

- 9.5.2.52 In the case of vibro-piling, ranges of effect are highly constrained and do not extend into critical intertidal habitat or the river mouths (Figure 9.10). The use of impact piling would have a much more extended effects range for cod and herring, potentially excluding these species from large areas of subtidal and intertidal habitats in periods when impact pile driving was taking place (Figure 9.11). Impact piling is predicted not to generate noise levels that would disturb salmon and sea trout migration routes, either across the Bay or to and from the Tawe and Neath river mouths.
- 9.5.2.53 Mitigation measures for potential noise impacts impact piling are discussed in Section 9.4.6.

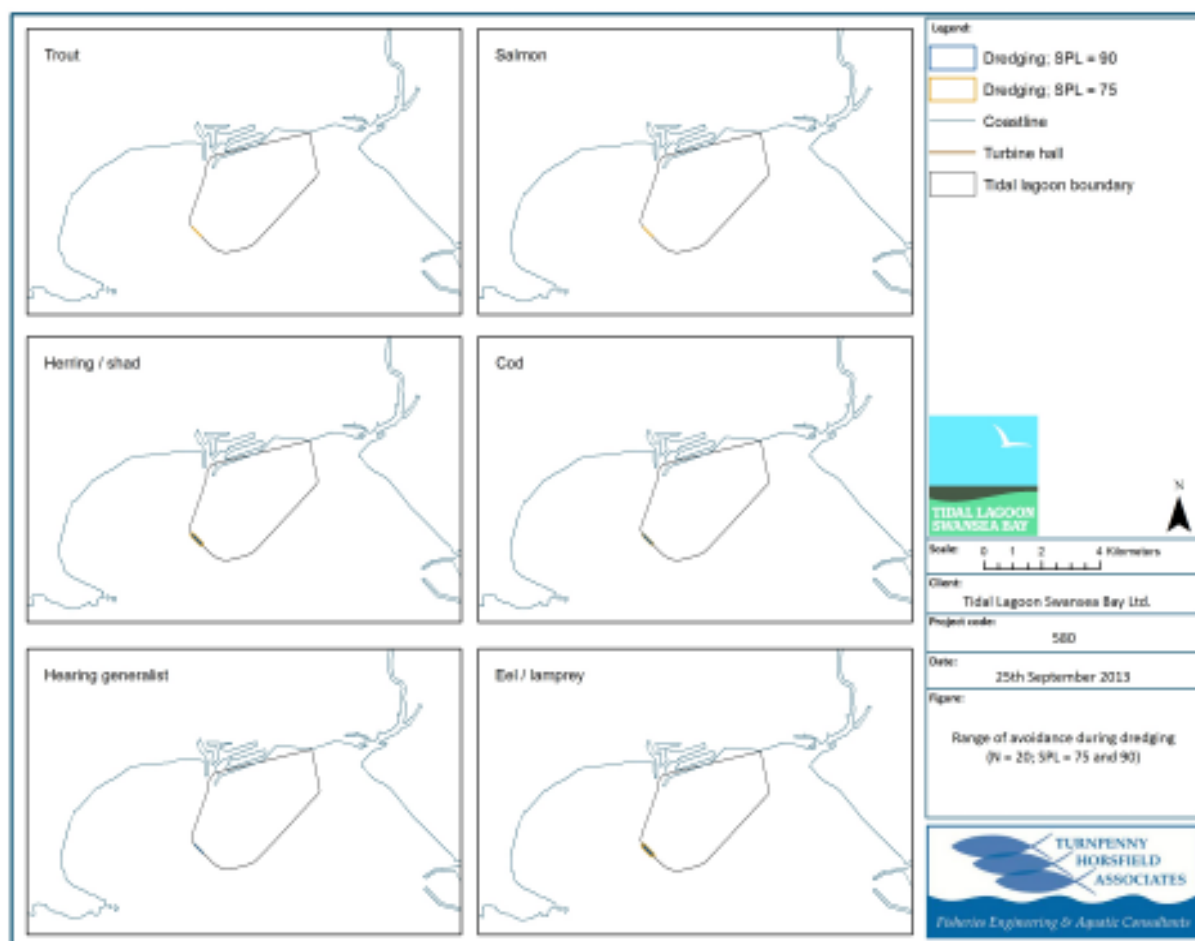


Figure 9.9 Ranges at which dredging noise is predicted to elicit a behavioural response from key species in Swansea Bay. Note: in the above image noise has been modelled around the turbines; whilst in effect it will be a mobile source of noise. Sound pressure levels (SPL) are given as dB above hearing threshold for the species.

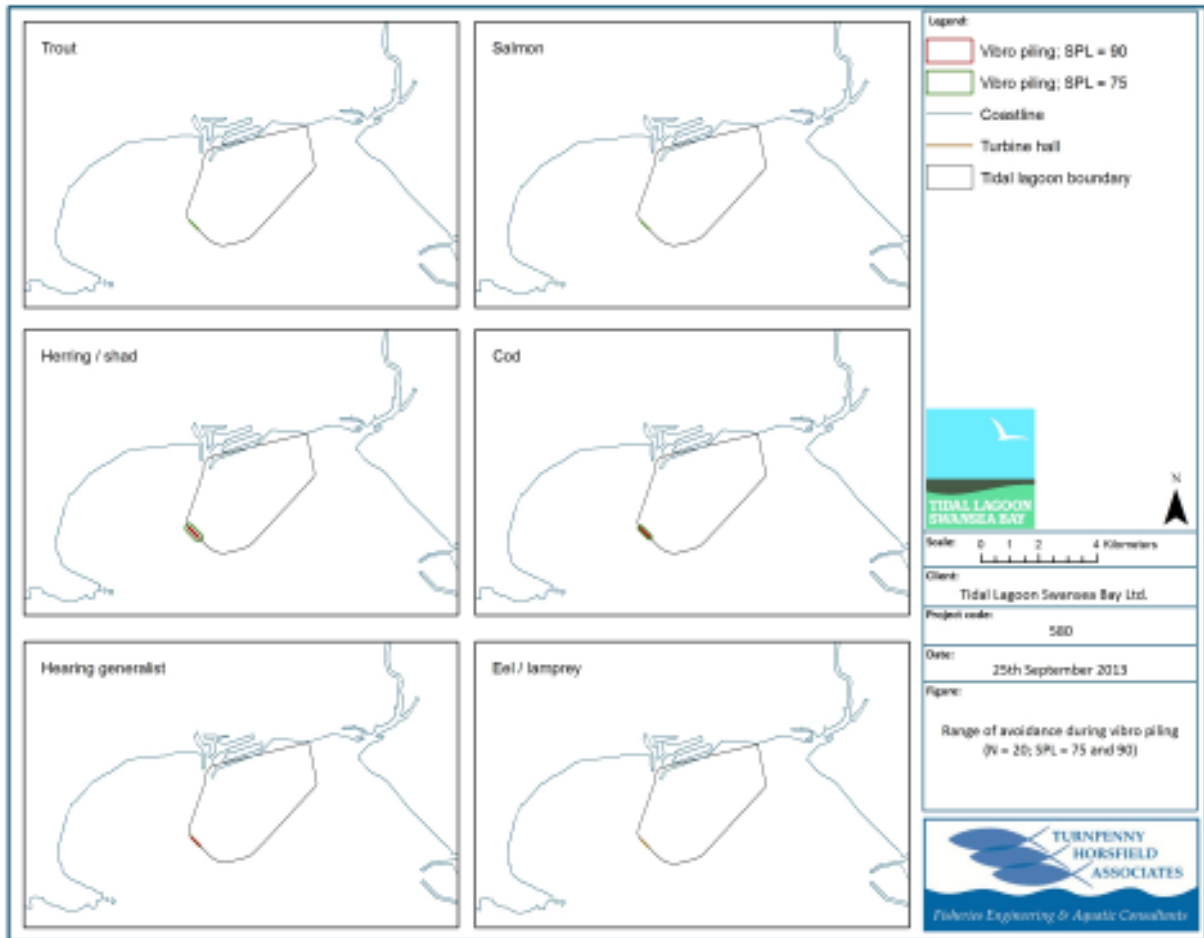


Figure 9.10 Ranges at which vibratory piling noise is predicted to elicit a behavioural response from key species in Swansea Bay. Sound pressure levels (SPL) are given as dB above hearing threshold for the species.

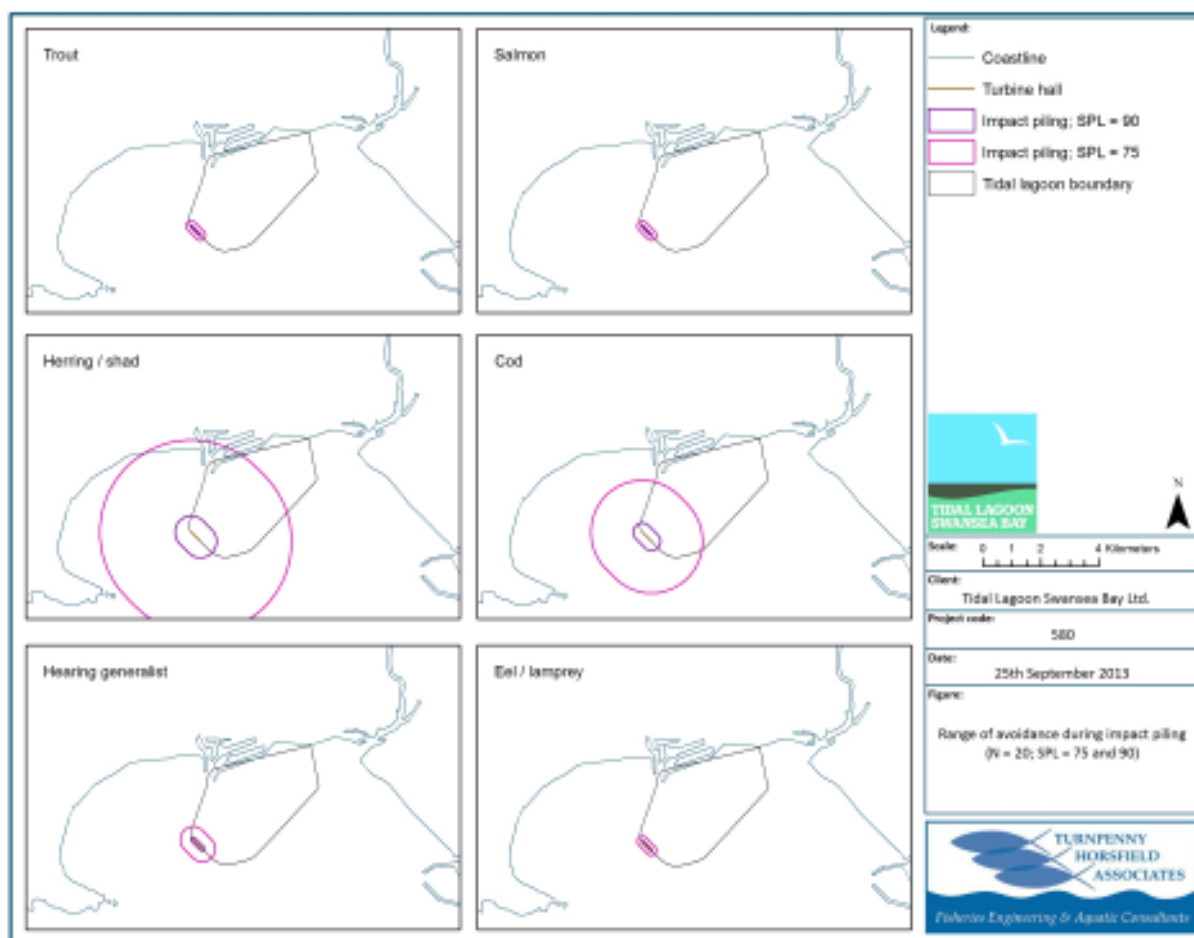


Figure 9.11 Ranges at which impact piling noise is predicted to elicit a behavioural response from key species in Swansea Bay. Sound pressure levels (SPL) are given as dB above hearing threshold for the species.

- 9.5.2.54 There are no known studies of the effect of sheet piling, dredging and placement of rock armour on mussels or native oyster. However, it is known that a related mussel (*Perna canaliculus*) can detect vessel noise because larvae settle more quickly in the presence of ship noise than in silence (Wilkins et al., 2012). But, without further scientific research, it is impossible to evaluate the effects of underwater noise on mussels or oyster.
- 9.5.2.55 There are no known studies of the effect of underwater noise on lobster. One study evaluated the effects of quarry blasting on American lobster *Homarus americanus*: Christian (2003) concluded that the effect of quarry blasting on American lobster would likely be negligible. There were a number of reasons, but the blasting was set back away from lobster habitat at distances considered safe under Canadian Government guidelines (Wright and Hopky, 1998). Parry and Gason (1996) suggest that sound associated with seismic surveys (typically 250 dB re 1 μ Pa @1m) has no effect on the catch-rate of rock lobster, a species closely related to lobster. Another decapod crustacean, brown shrimp *Crangon Crangon*, was found to have significantly lower growth and reproduction (Lagardere, 1982) when exposed to underwater sound. However, the sound was continuously applied by Lagardere. This would not be the case in the Swansea Tidal Lagoon. The underwater noise would be periodic during construction and after construction would be considerably lowered. Thus, the Swansea tidal lagoon situation appears similar to the quarry blasting situation assessed by Christian (2003) who concluded there were not likely to be significant impacts on lobster.



- 9.5.2.56 No studies of underwater sound effects on brown crab have been identified. The closest relative of the brown crab for which underwater sound, similar to that under consideration here, has been studied is the snow crab *Chionoecetes opilio*. Snow crabs with carapace widths from 75 to 115 mm were exposed to sound levels in experiments in Canada (Christian 2003; Christian et al., 2004). Snow crabs were exposed to 197 – 220 dB re 1 μ Pa and there were no tissue differences in control and sound-exposed groups. However, snow crab eggs did exhibit some effects from exposures to 220 dB re 1 μ Pa: more dead eggs and lower growth were observed in the eggs exposed to sound compared to the control eggs. However, the author cautioned that he assessed only one egg mass and thus the results regarding eggs should be viewed as preliminary.
- 9.5.2.57 No known studies have been conducted on the effect of sheet piling, dredging and placement of rock armour on velvet swimmer crabs. Another shallow water crab, the shore crab *Carcinus maenas*, which lives in water less than 65 m deep, is known to be sensitive to ship noise. Compared to ambient noise playback, ship noise playback disrupted feeding and led to riskier anti-predator behaviours (Wale et al., 2013). Thus, the potential for velvet swimmer crabs to be affected by underwater noise from the Swansea tidal lagoon construction activities exists. But, at this time it is not possible to further assess the effect.
- 9.5.2.58 Low-noise vibro-piling will be used for the majority of pile insertions; peak-to-peak sound pressure levels (SPLs) from this activity are in the region of 192 dB re 1 μ Pa @1m, with most energy in the sub-500 Hz range. In some instances (i.e. patches of hard substrate) impact piling may have to be used. Noise from this activity is typically higher than from vibro-piling, with peak source levels of typically 220 dB re 1 μ Pa @1m. Piling is scheduled to occur approximately between April and October.

Increases in artificial light emissions

- 9.5.2.59 The temporary bund required for the construction of the turbine and sluice gate housing will not be lit from the outside, although some navigational lighting may be needed where stipulated by health and safety requirements. During construction the other light sources will primarily be mobile (eg vehicles accessing along the seawall or vessels working offshore), intermittent and localised; they are anticipated to cause insignificant disturbance to fish and shellfish, except sea lamprey where there will be a minor temporary effect.

Habitat modification

- 9.5.2.60 During the construction phase, habitat modification will occur as a result of the introduction of the seawall, temporary rock storage on the upper intertidal area and temporary cofferdam. There will also be loss of/disturbance to habitat from the dredged areas which will be used to fill the Geotubes® to form the seawall. The total amount of material removed for construction dredging is anticipated to be in the region of 8.1 Mm³. Re-colonisation of a site following dredging typically starts to occur immediately (see Chapter 8 Intertidal and Subtidal Ecology for further information). However, the extent to which dredged areas recover is based on the period between dredging activities. Boyd et al. (2003) indicate that faunal assemblages in dredged areas can remain in a perturbed state for up to four years but the rate is thought to be site-specific. As a result, dredging for the Project could have indirect effects on fish through disturbance of the prey species associated with the sand/gravel seabed, although this will be offset to a degree through colonisation of the new Lagoon seawalls. Table 9.14



gives a summary of expected habitat modification during the construction phase of the Project. Habitat modification during the operational phase is presented in Table 9.15.

Table 9.14 Approximate habitat gains and losses expected during the construction phase of the Project.

Pathway	Habitat modification (ha)			
	Intertidal		Subtidal	
	- /Loss	+ /Gain	- /Loss	+ /Gain
Seawalls	20.50	38.00*	65.20	24.15
Temporary Area for rock storage	22.25	n/a	n/a	n/a
Capital Dredging	n/a	n/a	400.00 (temporary)	n/a
Temporary cofferdam	n/a	1.90	20.30	9.00
Total loss/gain	-2.85		Up to -452.35	

* habitat will start to be colonised as the walls are formed.

- 9.5.2.61 The worst case intertidal seabed loss (42.75 ha) represents 1.76 % of the total intertidal area within Swansea Bay coastal water body (2424 ha). This will be as a result of the creation of the seawall and rock storage area. The rock storage area is considered a temporary loss as habitat will be re-instated upon completion of the works. The intertidal habitat gain will commence as a result of the construction of the temporary cofferdam and the formation of the lagoon walls. The total area will be 39.9 ha which represents a 1.65 % increase of the total intertidal area within Swansea Bay.
- 9.5.2.62 The worst case subtidal seabed loss (476.5 ha) represents 4.6 % of the total subtidal area within Swansea Bay coastal water body (10,380 ha), of which 400 ha (3.85 %) will be as a result of dredging; 65.2 ha (0.63 %) as a result of the seawall; and 20.3 ha (0.22 %) as a result of the temporary cofferdam. The dredging of 400 ha should be considered as a temporary loss, as the area will re-colonise over time. The gain of subtidal habitat on the temporary cofferdam wall (9.0 ha) represents 0.09 % of the total subtidal area within Swansea Bay coastal water body. Again, the seawall and turbine/sluice gate structure will also provide new habitat as it is constructed, giving an extra 24.15 ha of rocky habitat (0.23 % of Swansea Bay coastal water body) once completed over the 3 years. For further information regarding habitat loss/gains see Chapter 4 Project Description.
- 9.5.2.63 The study area is a spawning/nursery zone for some of the VERs, the majority of which are pelagic spawners. Impact on spawning is likely to be minimal for most species, due to the abundance of similar habitat within the wider study area and further afield.
- 9.5.2.64 Existing intertidal habitat within the footprint of the Lagoon is dominated by sandflats (186 ha) and a relatively large *Sabellaria* reef (approximately 63 ha). *Sabellaria* are noted for their ability to form biogenic reefs; which serve to attract a variety of invertebrates and fish (Gubbay, 2007). Similar reefs have also been found to occur west of the River Tawe, and are not exclusive to the area within the bounds of the Lagoon. It should be noted that the introduced seawall could offer a habitat to future *Sabellaria* populations, as it will provide a stable substrate on which tube-worm populations could develop (see Chapter 8: Intertidal and Subtidal Ecology).
- 9.5.2.65 Subtidal habitat enclosed by the Lagoon forms approximately 9 % of the total available substrate within the Bay. Subtidal habitat within the Lagoon is fairly homogenous and consists of infralittoral coarse sediment, primarily populated by polychaetes, crustaceans and bivalves (see Chapter 8: Intertidal and Subtidal Benthic Ecology). These habitats, and food items, have an important role as nursery areas for flatfish (e.g. plaice) and ray (e.g. thornback ray). Survey data indicates that both juvenile flatfish and rays have been



captured at sites within the bounds of the Lagoon. Juvenile plaice have been noted to reach densities of up to 35 individuals per 100 m² in habitats with similar characteristics of Swansea Bay (Van der Veer, 1986). Survey data from July 2013 indicates that densities of plaice in Swansea Bay were highest at Port Talbot West (SS 73583 90341) and Abertawe (SS 66066 92221) (~9 individuals per 100 m²), whilst densities at Crymlyn Burrows (SS 70348 92472) were lower (~5 individuals per 100 m²). This suggests that areas outside the bounds of the Lagoon are more suitable for flatfish species. This trend continued in later surveys.

- 9.5.2.66 Unlike salmon, sea trout are likely to use Swansea Bay to forage. However, due to the limited size of the Lagoon footprint in terms of the available foraging habitat in the wider Bristol Channel, the impact of habitat loss and modification associated with the construction phase is not considered significant. Additionally, the project increase in invertebrates (e.g. crab), resulting from the introduction of the seawall, will likely prove beneficial to sea trout.

- 9.5.2.67 In the case of herring, loss of seabed associated with the temporary construction footprint could reduce available spawning area for the Swansea Bay stock during the construction phase. Recent accounts indicate that herring spawning occurs closer to the shore, in proximity to the entrance of the River Tawe, in an area called 'Swansea Rough' (Horsfall, I., pers. comm. 2013; Thomas, B., pers. comm. 2013). Herring spawning in this region most likely use the *Sabellaria* reef (63 ha) and shore defences found fronting the ABP owned land. Some fish are also known to spawn in proximity to Blackpill, a section of shoreline called 'The Baldy' (Wisby, I., pers. comm. 2013) (Figure 9.12). There is also evidence to suggest that the sea defences at the entrance of Port Talbot Dock are used by spawning herring (Thomas, B., pers. comm. 2013). This suggests that habitat introduced through the construction of the Lagoon seawalls can fulfil a similar ecological function (U.S. Army Corps of Engineers, 2013).

- 9.5.2.68 Should herring be able to use the newly introduced seawall habitat there will be an overall gain in spawning substrate. However, suitability will be affected by morphological conditions such as wave wash.

- 9.5.2.69 The impact on migratory species with bigger ranges (e.g. shad) which do not necessarily have a standing population within the Bay will be minimal. These fish undertake significant migrations at sea, and would be able to find suitable feeding grounds elsewhere.

- 9.5.2.70 Intertidal habitat introduced with the construction of the Lagoon seawall will be composed of natural rock. The new habitat will take some time to colonise, and will be replacing sand/gravel habitat with habitat of different characteristics. Ecological value will initially be low, however, once macrobenthic communities begin to establish themselves, the new intertidal and subtidal habitat will increase habitat heterogeneity, and potentially lead to an increase in diversity and abundance of fish and shellfish species (Inger et al., 2009). Leonhard et al. (2011) have shown that the introduction of hard substrates to homogenous sand banks associated to renewable energy developments can result in a net gain for marine fish biodiversity. For a summary of beneficial effects surrounding artificial reefs please see Jensen (2002).

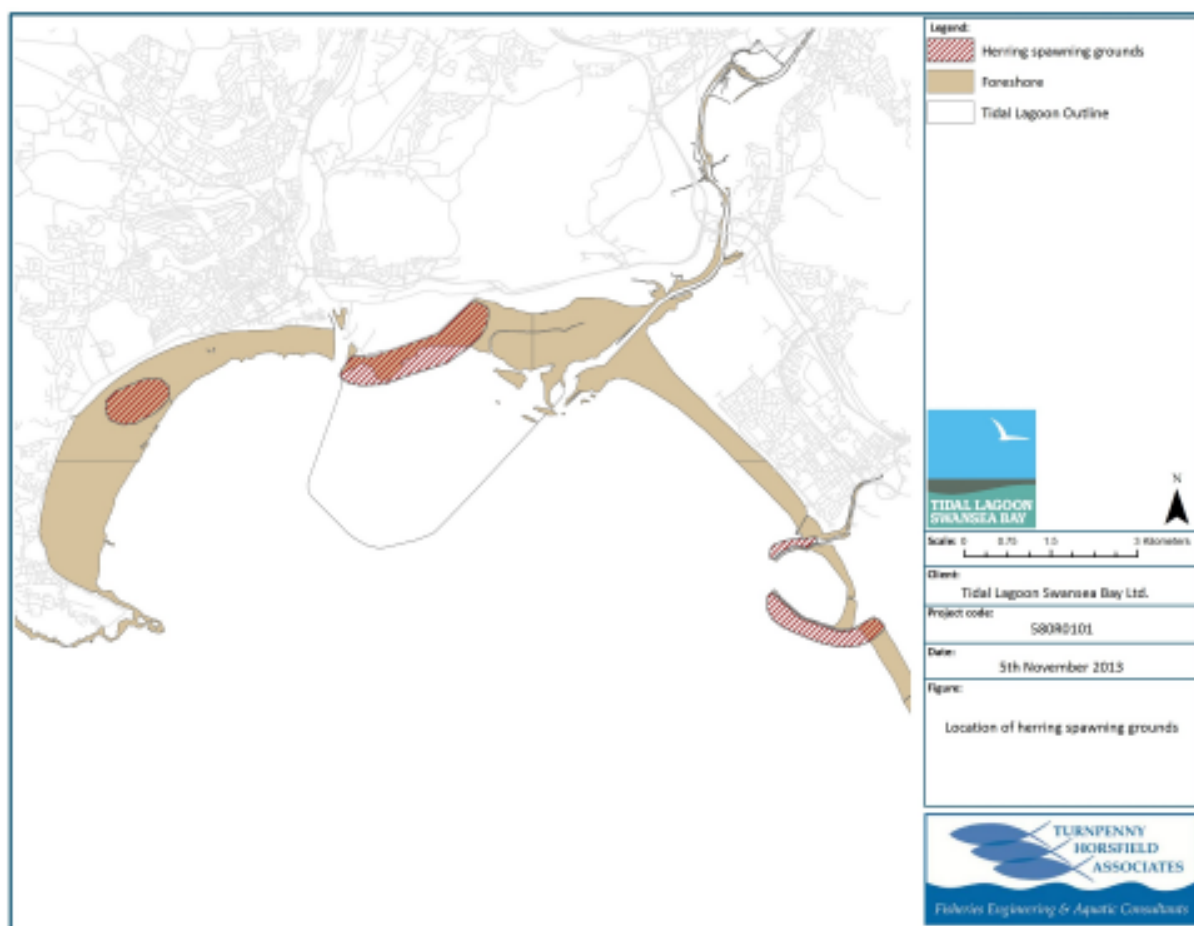


Figure 9.12 Identified herring spawning grounds within Swansea Bay

- 9.5.2.71 Artificial reefs have also been shown to positively impact the population size of commercially important shellfish and fish species, as well as increase the yield of fishing activity (Jensen, 2002). Structures of this kind support varied macrobenthic communities which in turn make the 'reef' more attractive to fish (Boaventura et al., 2006), increasing both density and biomass of local fish populations (Santos & Monteiro, 1997).

Habitat loss due to dewatering of cofferdam

- 9.5.2.72 The offshore construction compound which will be built around the turbine and sluice gate structure will be dewatered prior to continuation of construction works; it is expected that a total of 2.2Mm³ of water will be removed from the temporary cofferdam area. The likely impact of this activity will be mainly associated with a loss of benthic habitat, which is addressed above. Potential effects on fish and shellfish for the dewatering would comprise injury and mortality to any trapped fish during the pumping works.
- 9.5.2.73 The temporary cofferdam will be constructed and then dewatering will occur via pumping. Given the relatively long timescale which will be required to build the turbine housing/sluice gate structure, and associated construction noise, it is likely that mobile fish and shellfish will vacate the area prior to completion of the temporary cofferdam. During the dewatering, any effects on remaining fish can be mitigated by fish rescue techniques and use of fish-friendly pumps (Environment Agency, 2011c) (see Section 9.4.6). Fish species which bury in the sand may be more at risk (e.g. eel; sandeel),



however, the relatively small area affected and techniques used mean that mortalities should be insignificant.

- 9.5.2.74 Less mobile species, such as whelk, mussel and oysters are more likely to be affected by construction works. There is likely to be some mortality amongst these species unless mitigated. However, no bivalve beds have been identified within proximity of the planned location of construction (see Chapter 8: Intertidal and Subtidal Ecology) and areas to be capital dredged/dewatered will be oyster-dredged prior to construction and any oysters found will be translocated (see Section 9.4.6). In addition, given that the overall footprint of the temporary cofferdam is small as a proportion of available habitat within Swansea Bay and the lack of individuals found to be present within proximity to the proposed site, the impact on the overall populations of these species is projected to be insignificant.

Entrainment from draghead

- 9.5.2.75 Fish and shellfish have the potential to be entrained by dredging operations during the construction of the Lagoon. Relatively little is known about the potential entrainment rates of fish in marine dredging. The general consensus is that demersal and benthopelagic species, which live in close proximity of, or within the substrate, are most at risk. Nightingale and Simenstad (2001) have shown fish entrainment rates from hydraulic dredgers to range from 0 to 0.594 (fish yd^{-1}). Pacific sand lance suffered the highest entrainment rates, owing to their burial behaviour. Mortality from dredging activity is likely to be high for all fish entrained.
- 9.5.2.76 Within the context of Swansea Bay, the species most at risk from dredging entrainment are sandeel. Between 400 ha (9.6 % of the Bay) and 63 ha (1.5 % of the Bay) are expected to be dredged during the construction of the Project. Sandeel habitat represents approx. 5 % of area within the Lagoon (see Habitat fragmentation and isolation), thus the relative amount of suitable habitat which will be dredged is limited.
- 9.5.2.77 Sandeel overwinter in sandy bottoms, this typically occurs between autumn and winter, during this period they burrow into the substrate, making them more susceptible to entrainment. Dredging is scheduled to occur approximately between April and October, this would largely avoid the period in which they are most at risk.
- 9.5.2.78 Given the relative scarcity of preferred habitat within the Lagoon footprint, and the seasonality of dredging activity, the overall losses to sandeel are considered insignificant. For other species effects are considered to be within natural variation.

9.5.3 Operational phase effects

Increases in suspended sediment and deposition

- 9.5.3.1 During operation some sediment accretion is predicted to occur along the eastern Lagoon sea wall adjacent to Crymlyn Burrows owing to changes in water circulation (Chapter 6: Coastal Processes, Sediment Transport and Contamination). This would be in the intertidal area and could have some limited implications for fish and shellfish, with effects similar in nature to the ones discussed in paragraphs 9.5.2.2 to 9.4.2.29. Additionally, maintenance dredging within the Lagoon to remove deposited sediment (see Chapter 6: Coastal Processes for more details) could temporarily increase in suspended sediment whilst works are being undertaken, but is considered to be localised, intermittent and returning to background variation within one spring-neap tidal cycle. Dredged material will be disposed at the Swansea (Outer) grounds and



activity will be subjected to licensing requirements under the Marine and Coastal Access Act (2009) and regulated by NRW Marine Licensing Team. The effect of each impact is quantified for each VERs identified in Tables 9.28 to 9.38.

Habitat fragmentation and isolation

- 9.5.3.2 The spawning migration of fish into Swansea Bay is either diadromous (fish moving between sea and rivers) or oceanodromous (migrating wholly in the sea). The Tawe Barrage, located on the lower section of the Tawe Estuary is known to add delays to the migration of diadromous fish within the R. Tawe estuary, as are other obstacles within the Tawe catchment. Both Mee et al. (1996) and Russell et al. (1998) indicate that salmon typically move past the structure when the barrage is overtopped. This occurs during tides > 8.05 m which account for approximately 71 % of tides in Swansea Bay, additionally inundation only lasts for 16 % of the tidal cycle. Further discussion regarding the Tawe barrage is provided in paragraph 9.4.3.113 to Section 9.4.3.121.
- 9.5.3.3 In terms of the Lagoon, potential impacts would be associated with habitat fragmentation and isolation. These could comprise: loss of foraging habitat, delays in migration, fragmentation of migration routes and increased energetic costs.
- 9.5.3.4 Given the location of the development between the mouths of the Rivers Neath and Tawe, the proposed structure will not be a tidal barrier (i.e. physically blocking access to an estuary - and as such its similarity to the scheme at La Rance is limited), and will not therefore create a total exclusion physical barrier to migrating diadromous fish heading into, or out of, rivers (e.g. salmon, shad, eel and lamprey).
- 9.5.3.5 No rivers will be flowing within the bounds of the Lagoon. During periods of heavy rain it is expected that the DCWW long sea outfall which will be within the bounds of the Lagoon, will release treated ($1.3 \text{ m}^3 \text{ s}^{-1}$) and combined with screened storm water to a maximum discharge of approximately $3.1 \text{ m}^3 \text{ s}^{-1}$. This compares with around $6000 \text{ m}^3 \text{ s}^{-1}$ total turbine flow entering and exiting the Lagoon, being 0.02 - 0.05 % of the flows and hence any influence on salinity will be minimal (See Chapter 6: Coastal processes). The freshwater component discharged will also be small relative to storm flows in from the rivers Tawe and Neath (Q_{10} values of $30 \text{ m}^3 \text{ s}^{-1}$ for Tawe; Neath ungauged). As a result, it is expected that any fish holding in the Bay and waiting for high flows in order to start its migration, would be much more likely to follow freshwater cues from the rivers and would be unlikely to be distracted by this small input.
- 9.5.3.6 The Project could marginally increase the energetic cost to migrating fish: first, due to them having to navigate around the structure; and secondly, by concentrating currents along its boundary. However, the IBM constructed as part of the Project (Appendix 9.3, Volume 3) indicates that total delay, at most, would be two tidal cycles, and thus the effective energetic cost would be minimal. Potential refuges from flows will also be provided by the rock armour forming the Lagoon seawall, which will also provide foraging habitat.
- 9.5.3.7 Movement of fish between waters inside and outside the Lagoon will be restricted to passage via the sluice gates and through the turbines. The fish behaviour modelling (Individual Based Modelling – IBM – see below) has indicated that fish which enter the Lagoon may be delayed in their migration by at least one tidal cycle. The proportion of migrating adults and juveniles within the model that were trapped on multiple occasions was low in comparison to those caught once, in all cases. In a typical configuration, less than 10 % of fish that entered the Lagoon once, entered a second time, and multiple



subsequent passes decreased exponentially. Fish which passed multiple times through turbines were subject to default mortality probability using the STRIKER™ model for each pass (see paragraph 9.4.3.77 and sequence). Fish not trapped by the Lagoon directly were not delayed significantly on their migrations and reached the natal river or open ocean on the same tidal cycle as when migrating in the baseline (existing) hydrodynamic case.

- 9.5.3.8 The impacts of the Lagoon are likely to be higher for fish moving inshore to use particular habitat features within the bounds of the Project, e.g. herring, which are known to spawn within the western extent of the intertidal and shallow subtidal areas within the Lagoon boundary (Figure 9.12), or juvenile flatfish occupying intertidal habitat. Fish such as bass which undertake annual inshore migrations will be impacted to a certain extent, however, given that there is an abundance of similar habitat the effect will be negligible.

Habitat modification

- 9.5.3.9 Long-term (for the lifetime of the Project) habitat loss will occur from the formation of the Lagoon and as a result of the modification of existing hydrological regimes as a result of the operation of the turbines and sluice gates. Table 9.15 gives a summary of the worst case expected habitat modification during the operational phase of the Project.

Table 9.15 Approximate habitat gains and losses expected during the operation of the Project

Pathway	Permanent habitat modification (ha)			
	Intertidal		Subtidal	
	- /Loss	+ /Gain	- /Loss	+ /Gain
Presence of Lagoon wall and turbine /sluice gate house	20.50	38.7	68.48	24.15
Modification to hydrological regimes	64.88	n/a	n/a	64.88
Total loss/gain	- 46.68		+ 20.55	

- 9.5.3.10 During operation, there will be potential intertidal seabed loss (85.38 ha) primarily as a result of water level differences within the Lagoon. This represents 3.52 % of the total intertidal area within Swansea Bay (i.e. 2424ha). With the potential use of variable speed turbines the water levels would be returned closer to the natural level and therefore intertidal losses would be minimised i.e. there would not be an intertidal loss/subtidal gain of 62ha as a result of modification to hydrological regimes within the Lagoon. During operation the total gain of intertidal habitat (approximately 38.7 ha) represents 1.6 % of the total intertidal area within Swansea Bay. All of the habitat gain is expected to be as a result of the creation of the seawall and turbine and sluice gate house.
- 9.5.3.11 The worst case subtidal seabed loss directly under the Lagoon wall and turbine/sluice gate house (68.48 ha) represents 0.66% of the total subtidal area within Swansea Bay coastal water body (10,380ha). During operation, the total gain of subtidal habitat (89.03 ha) represents 0.86 % of the total subtidal area within Swansea Bay; of which 64.88 ha (2.68 %) will be from “intertidal losses” as a result of changes to water levels (see above) (2.88 ha within the wider bay and 62 ha within the lagoon), and 24.15 ha (0.23 %) as a result of the seawall and turbine/sluice gate housing.
- 9.5.3.12 The fish VERs most likely to be affected by this long term change potentially affecting foraging and spawning habitats are sandeel and herring as these species show some site fidelity (Clarke, 1984). Most of the fish species found within Swansea Bay are broadcast spawners and do not rely on specific substrates to spawn. Additionally, the majority of pelagic spawners spawn offshore and many of the species which visit Swansea Bay are



transient, this is clearly evident in the seasonal presence/absence of particular species (Appendix 9.2, Volume 3). As a result, most (with the exception of migratory species needing to enter the rivers, and the Swansea Bay herring spawning stock) are not wholly dependent on Swansea Bay.

- 9.5.3.13 The morphology of the habitat inside the Lagoon is likely to be altered as a result of the Project. In addition to the loss of habitat already mentioned, there is potential for changes to occur in bed composition, owing to changes in tidal currents. The area which will be enclosed by the Lagoon represents approximately 9 % of the overall substrate available within the Bay (including subtidal and intertidal); and approximately 0.2 % of the Bristol Channel as a whole (calculated as the area between the lower Severn River Crossing and the following coordinates (51°01'N 4°32'W - 51°36'N 4°55'W). In relative terms, the area which the Lagoon and its structures occupy is small when considered on this scale.
- 9.5.3.14 The habitat within the Lagoon is expected to have a healthy ecological function following the commencement of tidal generation. Unlike other non-generating amenity barrages (e.g. Tawe and Cardiff Bay barrages), where a high proportion of river water is primarily held back and little exchange occurs between the 'open' environment and the fragmented habitat within, the volume of mixing in this Project will allow modified but healthy marine ecological processes to continue. This will also be reliant on other characteristics such as sedimentation and water quality. Modelling has indicated a marginal increase in salinity within the Lagoon itself, this could result in a partial shift towards a more marine assemblage, as opposed to euryhaline. However, the temporary nature of these changes is likely to have no lasting effects. Sedimentation increases will be predominantly constrained to within the Lagoon, and in the near field, in the subtidal across the western side of the Bay, within Swansea Channel (inner area) and in the region fronting Crymlyn Burrows, and are not considered to have lasting effects on the composition or abundance of the fish and shellfish population within the Bay.
- 9.5.3.15 Species which occupy lower levels in the trophic chain, and are not necessarily important from a commercial standpoint, are nevertheless ecologically important as they play a major role in the marine food-web. Sandeel, sprat and herring are prey for many piscivorous fish including salmon, sea trout, turbot and rays. Surveys undertaken in 2013 across intertidal sites indicate that these prey species are common across the Bay. Fish generally feed on a range of food items (Harris & Milner, 2004; Aas et al., 2011), thus, their sensitivity to a temporary change in a particular food resource is not considered to be high.
- 9.5.3.16 Cefas have indicated that sandeel are an important ecological resource. Although the quarterly fish surveys did not yield particularly high numbers in the Lagoon footprint (Intertidal site 6 - winter 0, spring 0 summer 16, and autumn 2) potential sandeel habitat has been modelled using ArcGIS 10.1 mapping techniques on substrate data collected within Swansea Bay (Figure 9.13; for more information see: TLSB geophysical and geotechnical surveys; Chapter 4: Project Description; and Chapter 6 Coastal Processes). Natural-neighbour interpolation was undertaken to map the availability of preferred sandeel substrate type within Swansea Bay. Preferred particle size was estimated by Holland et al. (2005) to be between 0.25 to 2 mm. Owing to the resolution and locations of the substrate surveys, and limitations involved with interpolation on this scale, caution should be taken in interpreting these figures. For instance, intertidal areas which can hold significant numbers of sandeel are not included in the analysis, as Particle Size

Analysis (PSA) data was not available for all areas. As a consequence, the estimate is conservative.

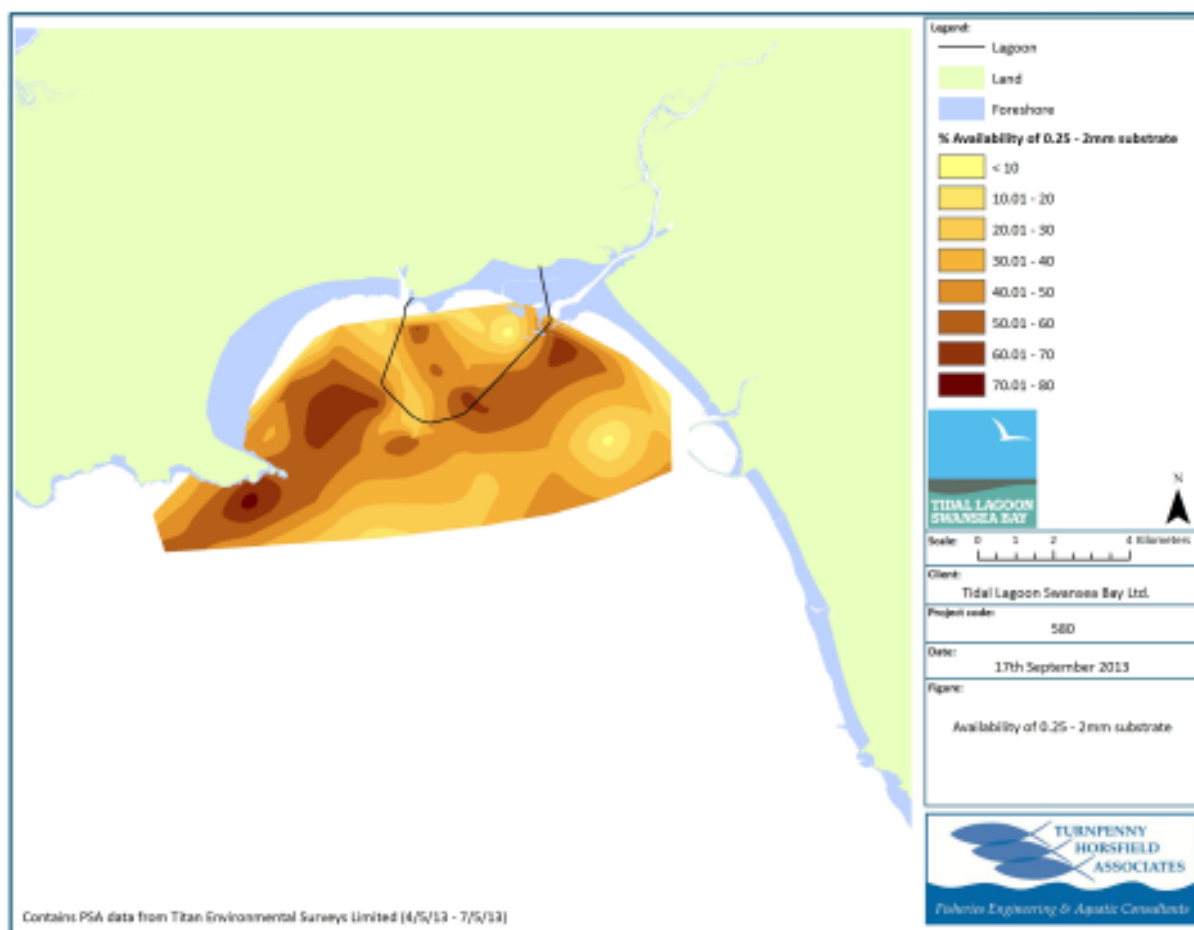


Figure 9.13 Modelled availability of potential sandeel habitat in Swansea Bay

- 9.5.3.17 Calculations indicate that 16.4 km² of substrate within the area modelled contains in excess of 50 % of sediment between 0.25 and 2 mm in diameter (i.e. assumed to be suitable for sandeel), of which 0.84 km² is within the bounds of the Lagoon. In this instance 50 % has been ascribed as the threshold value. However, sandeel may be present in areas which have less, or more, than this level of preferred sediment. This results in an approximate fragmentation or loss of around 5 % of the preferred habitat of sandeel within the area modelled according to the stipulated criteria. This should be viewed in the context of the site-specific fish surveys which indicated the number of sandeel were significantly greater to the east and west of the Lagoon site.

Increased predation

- 9.5.3.18 Fish passing through, or near to, the turbines comprised in the Project will be subjected to turbulence of high energetic intensity and short length-scale, which is rare in the natural oceanic environment.
- 9.5.3.19 Turbulence, especially that with high mixing efficiency caused by high energetic intensity and short length scales, is a critical factor for inducing a high abundance of plankton (Margalef, 1978). Thus, it is likely that planktivorous fish will be attracted to areas of predictable high turbulence caused by the new turbines in the same way they are presently attracted to turbulence in fast moving tidal currents around complex rocky



coastlines (i.e. South of The Mumbles). Where foraging fish are attracted, so are their predators, including larger piscivorous fish. However, fish are attracted to these zones because they are able to access a richer zooplankton resource than they would otherwise be able to find locally, and thus this may lead to a positive feedback cycle and a more resilient and higher abundant population of resident foraging fish and their predators in Swansea Bay (Willis, 2013).

- 9.5.3.20 Fish, or schools of fish which are drawn through the turbines may be negatively impacted by a loss of school integrity. This and general individual disorientation after a turbine passage, may make obligate schooling species more vulnerable to predation, even if they are not injured in their passage through the turbines.
- 9.5.3.21 Predation of juvenile clupeids by bass and gulls in the turbine tailrace at La Rance Tidal Barrier has been reported by Solomon (1988), although the level of predation was not quantified.
- 9.5.3.22 Juvenile diadromous fish (e.g. smolt) emigrating from rivers could potentially face increased predation as a result of the increases expected in the numbers of bass attracted by the habitats created by the Project. Smolts are expected to migrate at night and thus avoid predators such as cormorants, but fish species such as bass hunt nocturnally. However, the potential seasonal overlap between emigrating juveniles and the arrival of adult fish such as bass is small (namely smolts will leave the rivers mainly in April-May and bass move inshore in June). As a result it is expected that effects of smolt predation from bass will be minimal. Other piscivorous fish, such as cod, may have some impact, though given their relatively low numbers in the area the overall effects will be limited. Mammals, such as seals, are also known to pose a predation risk to fish, especially migratory salmonids. However, within open water, the likelihood of mammals posing an increased risk to fish is low. Predation pressure from mammals is of concern where fish can be trapped against structure (e.g. fish pass), and given that the sea wall will provide abundant cover for fish, mammalian predation is not considered an issue.
- 9.5.3.23 Fish may also face an increased risk of predation as a result of turbine passage. Turnpenny et al. (1992) examined survival of simulated turbine-passage stresses on fish over a period of up to seven days post exposure. The stresses associated with the turbines are discussed further in the next section. The extended monitoring period during the trials allowed delayed mortalities to be assessed, as well as recovery from injury. Some types of trauma, for example swimbladder rupture, will heal with time as evidenced by scar tissue on fish subjected to pathological examination after this extended monitoring period. Nonetheless, it has generally been assumed for worst case environmental assessment purposes that any fish injured during turbine passage will be sufficiently disadvantaged in predator confrontations to count them as dead.
- 9.5.3.24 The question of whether uninjured fish that have passed through a turbine are similarly put at a disadvantage in such confrontations has been investigated. Odeh et al. (2002) exposed a variety of salmonids and percid fish species to turbulence levels typical of turbine passage, then subjected them to the silhouette of an avian predator (61 cm wingspan cormorant). While some reduced startle response was evident, no statistically significant response could be demonstrated. Subsequently, Čada et al. (2003) developed a technique to measure the 'C-start' escape response in fish subjected to sublethal stresses. Čada et al. (2006) applied this technique at the Wapanum hydroelectric site, to fish that had passed through the ~ 7 m runner-diameter turbines. They measured the C-start response at 1, 5 and 15 min after collection, and compared these to non-turbine-



passed controls and were unable to detect differences between test and control groups. Both groups of authors offer cautions in the interpretation of their findings on the basis of sample sizes and handling techniques employed.

Entrainment and injury risk from the turbines

- 9.5.3.25 Hydroelectric turbines have the potential to injure or kill fish which are entrained within the generating flow. This can occur as a result of collision with the rotating turbine blades, or due to changes in pressure, severe turbulence or hydraulic shear stress. Risks typically increase as fish increase in length and mass, and sensitivities vary amongst species (Turnpenny, 1997).
- 9.5.3.26 No studies on effects of tidal turbines on eggs and juvenile stages of fish have been identified. However, studies carried out in freshwater environments in the context of hydropower have indicated that bulb turbines have a relatively low impact on early life stages of fish. Shear forces and pressure changes created by turbines are thought to have potential effects on around 5 % of ichthyoplankton, whilst blade strike is thought to affect around 0.1 % of fish eggs < 1 mm and < 2 % of fish larvae (Cada, 1990). As described below, pressure changes in tidal power turbines are small compared with most inland hydropower schemes and therefore pressure-related effects are likely to be less than 5 %. STRIKER™ v.4 model figures estimated below for pressure effects on adult fish in the 0.33 % to 2.6 %, offer the best indication of likely effects of turbine passage on ichthyoplankton, as the mechanisms for injury are likely to be similar.
- 9.5.3.27 Numbers of fish will enter and leave the Lagoon, following tidal water movements or to access different seasonal habitat requirements. For example, young flatfish move into shallow tidal waters (surf zone) during their first summer, and move out into deeper, warmer waters in autumn or winter. Some can be expected to enter the Lagoon by chance, including migratory species such as salmon, sea trout or eel, as they attempt to locate the adjacent local river mouths of the Rivers Tawe and Neath. Of those entering or leaving the Lagoon, a proportion will pass through the sluice gates (open during periods near high and low water) and others will pass through the turbines. Water velocities passing through the turbine housings are estimated to be 10-11 ms⁻¹ during power generation, hence they are well in excess of swimming abilities of any fish likely to be present and any passage through the turbines is likely to be in the direction of flow only.
- 9.5.3.28 In order to assess the risk of injury caused by turbine operation, two types of computer modelling were applied to the Project:
- Fish behaviour modelling:** This stage used a process known as “individual-based modelling” (IBM) to predict how fish of a given species will react to water currents and topographical features. IBM modelling allows the frequency of turbine encounters by fish to be estimated, and also the number of times a specific type of fish, such as a salmon, is expected to pass through a turbine as a result of tidal incursions and excursions. The IBM generates figures representing e.g. the percentage of the year’s run of salmon adults or smolts that would be expected to pass through the turbines ($P_{\text{encounter}}$), or the proportion of the local flatfish population that will pass through the turbines in a season.
 - Turbine injury rate modelling:** The second stage used a turbine passage fish injury rate model (STRIKER™ v.4) to estimate the percentage of fish (P_{injury}) passing through a turbine, identified by the IBM, that are likely to be injured. STRIKER™ v.4 estimates injuries resulting from collision with the fixed or rotating turbine blades, or from other physical stresses such as pressure change and turbulence. For



environmental assessment purposes, a worst case has assumed with regard to injuries sustained, and it has been assumed for modelling purposes that all injured fish do not survive

- 9.5.3.29 Predicted overall population mortality (F') due to turbine passage is calculated as:

$$F' (\%) = P_{\text{encounter}} (\%) \times P_{\text{injury}} (\%) \quad \text{Equation 2}$$

In practice, this is calculated dynamically by the IBM following the path of each individual fish, thus taking account of probability of multiple passages.

IBM fish encounter modelling

- 9.5.3.30 A comprehensive description of the IBM fish behaviour model is set out in Appendix 9.3 (Volume 3). A brief description only is given here. This type of model has previously been used and validated by the US Army Corps of Engineers in North America to model behavior of fish approaching dam spillways and sluices (Goodwin et al., 2006, 2007), an application not dissimilar to the tidal lagoon application. An IBM was also used in Severn Strategic Environmental Assessment to model smolt entrainment into lagoons (HRWallingford, 2009).
- 9.5.3.31 Fish behaviour in coastal waters is highly dependent on tidal water movements and on features such as water depth and habitat characteristics (Herbert et al., 2011). Diadromous migratory species also use characteristics such as the earth's magnetic field (Willis et al., 2009), fluvial flow and associated salinity changes and olfactory cues to find their way into river systems. Features of the Project that may affect these behaviours include physical impedance by the seawalls, changes to hydraulic patterns, interactions with the turbine and sluices and temporary entrapment within the Lagoon. Changes in patterns of tidal movement can also be envisaged to have the potential to alter the course of olfactory trails, confusing fish attempting to find local rivers. In the context of Swansea Bay, the rivers of key interest are the Rivers Tawe and Neath, which enter the Bay just outside the western and eastern landfalls of the Lagoon seawalls respectively. Hydraulic modelling has indicated that flows from and to the R. Ogmere and R. Afan will remain unaltered following the construction of the Lagoon, as they are hydrologically isolated, consequently they have been excluded from the IBM as there would be no modelled effects
- 9.5.3.32 Individual-based models (IBMs) of fish behaviour track movements of large numbers of individual particles programmed with attributes of fish (virtual fish) within a hydrodynamic model (Willis, 2011). In this case the hydrodynamic model used is the MIKE21™ model, set up by ABPmer to model movements of water in Swansea Bay, without the Lagoon (baseline case) and with the Lagoon in place and operating (operational case). The model represents water movements over a full spring-neap tidal cycle and fish behaviour can therefore be represented over the full tidal cycle. The primary purpose of the model is to predict the number of fish from populations of the selected key and indicator species and lifestages that would come into contact with the turbines and sluices over an annual cycle, so that mortalities caused by turbine passage could be assessed. Additionally, the modelling provides 2-dimensional visualisations of modelled fish behaviour patterns. The species modelled (Table 9.16) were identified through the baseline study (Appendix 9.1, Volume 3) as being present in the near-field study zone and were selected for their commercial, conservation or recreational importance and to cover a wide range of behavioural types. Species such bass, gadoids and flatfishes are intended to act as surrogates for a wide range of roundfish and flatfish

that are seasonally or permanently resident in the Bay and environs. Table 9.16 explains the rationale for inclusion of these species.

Table 9.16 Fish species and lifestages that have been considered in IBM fish behaviour modelling

Fish Species /Group	Swimbladder Type	Reason for Selection as Indicator Species
Atlantic salmon & sea trout smolt.	Physostome	Nationally important migratory fish, identified as a BAP priority species.
Atlantic salmon & sea trout adult.		
Atlantic salmon & sea trout kelt.		
Shad adults.	Physostome	Species of international conservation importance.
Herring	Physostome	Spawning known to occur within the Bay.
Glass eel/elver.	Physoclistostome	Species of international conservation importance.
Silver eel	Physoclistostome	
Gadoids (cod, whiting, bib, hake etc.).	Physoclist	Species group of regional commercial value.
Bass	Physoclist	Species of regional commercial value.
Flatfish (plaice, sole, dab, rays).	Non-functional or no swimbladder.	Species of regional commercial value.
River Lamprey	No swimbladder.	Nationally important migratory species.

9.5.3.33 The model of virtual fish is based on a model of a drifting particle to which is added an individual swimming velocity at each time step in the model. Models of drifting particles are well advanced and standard methods were used (Willis, 2011). The difference between a randomly drifting particle and a virtual fish in the model is determined by establishing a number of rules of behaviour that are applied to the particles to simulate fish behaviour. The justification for doing so is well established (over more than 20 years) and the model developed for the Project adopted existing best practice (Willis, 2011). These rules can include positive or negative rheotaxis (reactions to water current direction); swimming performance; depth preferences (e.g. to ensure that fish in the surf-zone of a beach follow the tide down the beach); magnetic compass bearing; response to olfactory stimuli; salinity preference; tidal state, and any other factors that can be introduced and synchronised with the model time such as wind, rain, sunlight and so forth. However, the most effective IBM models focus on a small number of key variables that are important to a fish in the context in which the model is being applied. A small number of rules and variables allow the models to be calibrated effectively across their entire range of functionality. The aim of the calibration is to ensure that the models are plausible in so far as they are not falsified by any known information about the target species, and that they accurately represent the implications of expert opinion within known confidence limits. Calibration is most accurate where the target of the model is a definite activity, bounded in space or time, where there is reasonable confidence in the motivation of the fish and where there is often extensive information and expert knowledge. For instance, ontogenic migrations (ones which are part of the fish's normal life history) of populations of salmon and trout are good targets for this type of modelling. There is extensive information on calibration and model uncertainty included in Appendix 9.3 (Volume 3). Table 9.17 presents a summary of behaviours modelled and behavioural rules applied in the model for given fish species.



Table 9.17 Summary of behaviours modelled and behavioural rules applied in the model (see Appendix 9.3, Volume 3).

Fish Species /Group	Ontogenic target of model	Particular rules applied to model fish species
Atlantic salmon & sea trout smolt	Migration in (adult) and out of natal rivers –Tawe and Neath, Wye, Usk and Severn (smolt and kelt)	Beach avoidance Minimum depth Olfactory trail
Atlantic salmon & sea trout adult		
Atlantic salmon & sea trout kelt		
Shad adults	Migration along coast towards Wye, Usk and Severn	Beach avoidance Minimum/maximum depth preferences Olfactory trail
Herring	Spawning within Lagoon	Navigate to spawning areas within Swansea Bay
Glass eel /elver	Inward migration – Tawe and Neath	Beach avoidance Multi-river olfactory trails
Silver eel	Outward migration – Tawe and Neath.	i. Freshwater targets. ii. Vertical positioning (daylight). iii. Vertical positioning (tide state).
Gadoids (cod, whiting, bib, hake etc.)	Inhabitation –Swansea Bay and environs.	i. Dispersive drifting. ii. Beach avoidance.
Bass	Inhabitation and interaction with shallow intertidal feeding zones –Swansea Bay and environs.	i. Beach avoidance. ii. Sensitive depth selection. iii. Homing to initialisation area. iv. Navigation dependent on tidal state.
Flatfish (plaice, sole, dab, rays)	Inhabitation–Swansea Bay and environs.	i. Substate sub-model. ii. Depth orientation. iii. Beach avoidance.
Lamprey	Migration in (adult) and out of natal rivers (transformer)-Tawe and Neath.	i. Beach avoidance. ii. Multi-river olfactory trails. iii. Freshwater targets. iv. Vertical positioning (daylight). v. Vertical positioning (tide state).

9.5.3.34 The models for each species used a standardised set of baseline runs and parameters for the virtual fish objects. The total number of fish objects in each model run was 10,000. This is viewed as 10,000 instantiations of the same model for the purposes of calculation of the probability of any particular outcome. The model time step was 60 s. All the model fish avoided land using the method of turning 90° left or right (chosen randomly) when next to a boundary and all were modelled using a correlated random walk. A custom function was added to ensure fish were unlikely to be left on a dry beach after the tide has ebbed which reflects reality. Many fish are known to be highly sensitive to chemical cues in the water which they can sense in an analogous way to humans' sense of smell. These form olfactory trails, which stretch out from the target location (the source - usually a natal river or the open ocean). The model fish navigate using the trails. For diadromous species, the model was run with passive drifting particles originating from the home rivers to model the position of these olfactory trails. These passive drifters had a limited lifetime in the water (7 days) and their density was used to define the trail. In all cases, the trails are very approximate route markers as is likely to be true for the real system (see Appendix 9.3, Volume 3).

9.5.3.35 Each of the biological variables in the model (e.g. fish length, swimming speed) was sampled from a normal distribution of values around a mean value $\pm$ standard deviation.

The large number of virtual fish used in the models was to ensure that the natural variability could be expressed via the statistical distributions of parameters. Wherever possible, data from scientific papers were used to define these parameters. Some parameters, such as swimming speed, were taken directly from the scientific literature, whereas others, such as ground speed¹, were matched through calibration of navigational parameters. This process and supporting published data are discussed in detail in the Appendix 9.3 (Volume 3).

- 9.5.3.36 Where there was no existing scientific evidence or expert opinion about a parameter (for instance exactly where fish are located in the Bristol Channel before they start their directed navigation to the river mouth), parameter values for the model were chosen from a uniform random distribution in the area most likely to be a source of impacted individuals. Wide boundaries of plausible values were therefore used which would lead to maximum potential impact, giving, therefore, conservative assumptions. Figure 9.14 shows the rectangle of starting positions assumed for glass eel approaching from the west. Examination of tidal currents in the water model indicated that water entering circulation in Swansea Bay extended Southwards only as far as the bottom of the rectangle; south of this line the current would naturally lead fish further into the Bristol Channel/Severn Estuary.

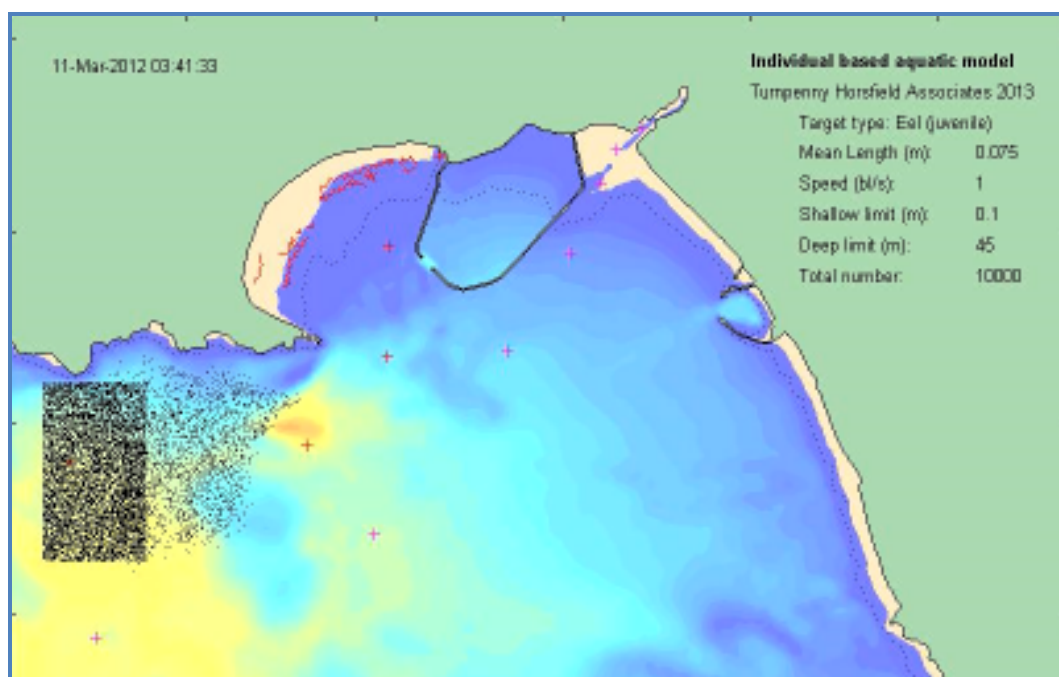


Figure 9.14 Section of still frame of model video output. Glass eels are initialised in the main channel in a uniform random pattern within the area from which there is maximum likely impact. Their start times are taken from a uniform random distribution over 8 hours before and after a high spring tide (the temporal zone of maximum potential impact) and so some can be seen to have started while others have not. The red crosses represent potential freshwater navigational trails to the R. Tawe and R. Neath. The red lines on the beach are ancient fish traps. The background colours represent depth contours at the state of tide when the model started.

¹ Ground speed is the horizontal speed of the fish relative to the ground (seabed/riverbed)



9.5.3.37 In the following sections video still-frame shots are shown for illustration, the full video file will be available to be viewed with the EIA via a web link (<http://tidallagoonswanseabay.com/environmental-statement-other.aspx>). Table 9.18 below lists the model runs and filenames ('scenario identifiers').

Table 9.18 List of model runs and filenames ('scenario identifiers')

Species	Scenario identifier	Mean swim speed (m/s)	SE swim speed	Min swim speed	Max swim speed	Mode
Salmon adult	TEM-A01	0.9	0.12	0.41	1.36	Trail follow
Salmon smolt	TEM-J01	0.18	0.02	0.12	0.24	Trail follow
Sea trout adult	TEM-A02	0.52	0.02	0.43	0.59	Trail follow
Sea trout smolt	TEM-J02	0.28	0.02	0.21	0.35	Trail follow
Shad	TEM-A03	0.52	0.07	0.28	0.78	Trail follow
Herring adult	TEM-A04	0.45	0.02	0.4	0.51	Homing zone
Eel adult	TEM-A05	0.75	0.2	0	1.51	Trail follow
Eel elver	TEM-J05	0.07	0.01	0.04	0.11	Trail follow
River Lamprey adult	TEM-A06	0.35	0.03	0.26	0.45	Trail follow
River Lamprey transformer	TEM-J06	0.16	0.02	0.1	0.22	Trail follow
Sea Lamprey Adult	TEM-A07	0.6	0.05	0.41	0.81	Trail follow
Sea Lamprey transformer	TEM-J07	0.22	0.02	0.11	0.32	Trail follow
Bass adult	TEM-A08	0.3	0.05	0.12	0.48	Area usage
Bass juvenile	TEM-J08	0.1	0.05	0.1	0.29	Area usage
Plaice juvenile	TEM-J09	0.08	0.01	0.04	0.11	Area usage
Neath adult salmon	TEM-A10	0.9	0.12	0.41	1.36	Trail follow
Sandeel	TEM-A11	0.4	0.1	0.03	0.76	Area usage

9.5.3.38 Salmon were modelled at the point in their life-cycle where they migrate into and out of their natal rivers. At longer distances from natal rivers, magnetic bearings play a greater part in navigation (Bingman & Cheng, 2005) but at this proximity the model is completely defined by navigation along olfactory trails emanating from natal rivers (Quinn, 2005). Recent evidence from acoustic tracked adult salmon (Davidsen et al., 2013) provides good evidence of the effective accuracy of their navigation and provides scientific knowledge on their instantaneous swimming speeds. Detailed calibration information is given in Appendix 9.3 (Volume 3). The model included a function to ensure the salmon did not swim onto the beach while it was drying. Figure 9.15 is a still-frame example from the adult salmon model video (<http://tidallagoonswanseabay.com/environmental-statement-other.aspx>) showing the splitting of Tawe and Neath fish as they follow olfactory trails towards their natal rivers. The large number of virtual fish in this view is unrealistic, but reflects what in reality would occur over a large number of tides during the river entry season. The model shows that olfactory trails from the two rivers remain quite distinct with the Lagoon in place and turbines and sluices operating, allowing adult salmon to home to their natal rivers with minimal distraction. Results demonstrated that there is no significant effect on olfactory trails as a result of water being drawn in to the Lagoon and released again.

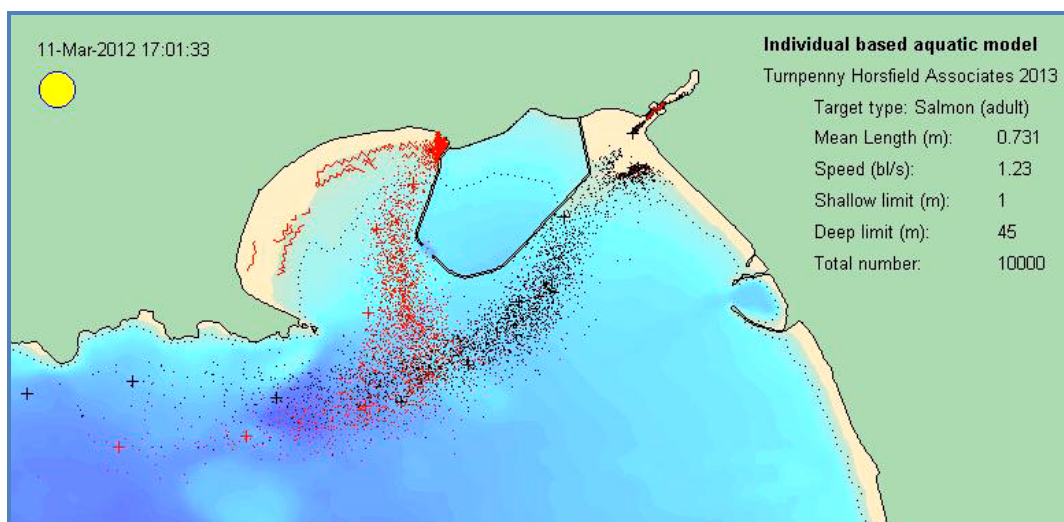


Figure 9.15 Section of a still frame showing adult salmon entering the R. Tawe and R. Neath.

- 9.5.3.39 Salmon and sea trout smolts migrating from the rivers Tawe and Neath to sea were modelled leaving the rivers on an ebb tide, reflecting knowledge obtained from UK smolt tracking studies in the Tawe and other UK estuaries (Mee et al., 1996; Moore et al., 1998). Figure 9.16 shows an example of smolts emigrating from the R. Tawe.

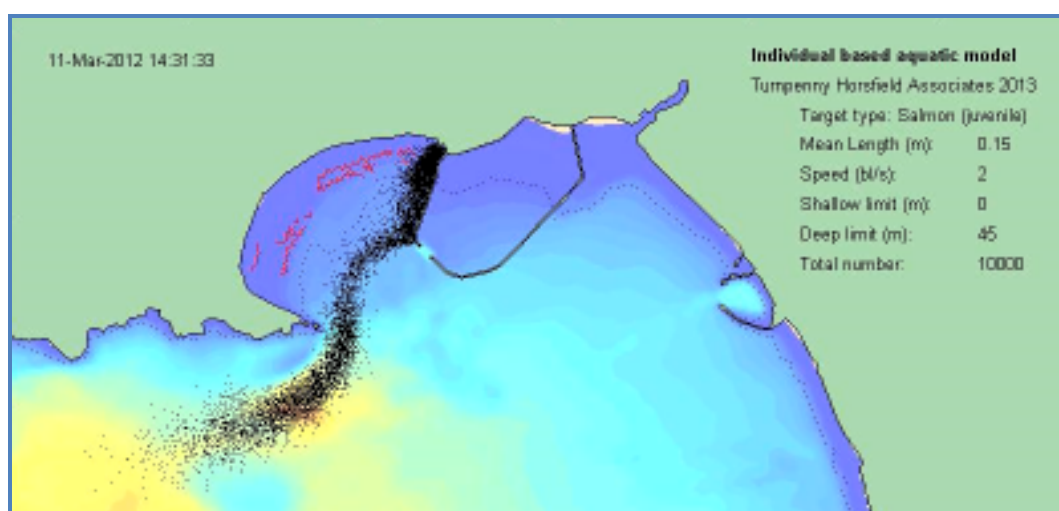


Figure 9.16 Section of a still frame of video output showing salmon smolt leaving the R. Tawe en route to the ocean. These fish are 15 cm long on average and swim strongly in a well-directed course as has been calibrated and validated through tagging studies. The start times are staggered over the top of a spring tide. The deflection caused by the discharge from the Lagoon can be seen.

- 9.5.3.40 The hydraulics encourage rapid dispersion to sea and modelling indicates minimal interaction with the turbines and sluices. The sample size of 10,000 fish used in this and other fish models is not necessarily representative of actual population size but is selected to give good statistical representation, and smolts would in reality emigrate over a more extended number of tides, whereas here they are shown as entering the Bay in a single concentration to make the illustration clearer. It should be noted that regulators such as NRW recognise that barriers to migration, such as river weirs, are a significant factor in WFD fish failures in the freshwater waterbodies linked to Swansea Bay (the Tawe, Neath, Afan and Kenfig catchments). For instance, the current barrage at

the mouth of the River Tawe has been shown to have a significant effect on salmon and sea trout movements (Mee et al., 1996; Moore et al., 1998). A later study by Washburn (2007), suggests that modification to the fish pass to improve energy dissipation levels within the pools in 2001, now allows fish to migrate under a wider range of environmental conditions.

- 9.5.3.41 Adult sea trout were modelled in a very similar way to salmon, with appropriate changes to size and, therefore, swimming speeds. Figure 9.17 is a still-frame example, showing more interaction with the turbines and sluices compared with salmon, leading to increased entrainment. This arises from the lower swimming speeds of sea trout, being on average smaller than returning adult salmon.

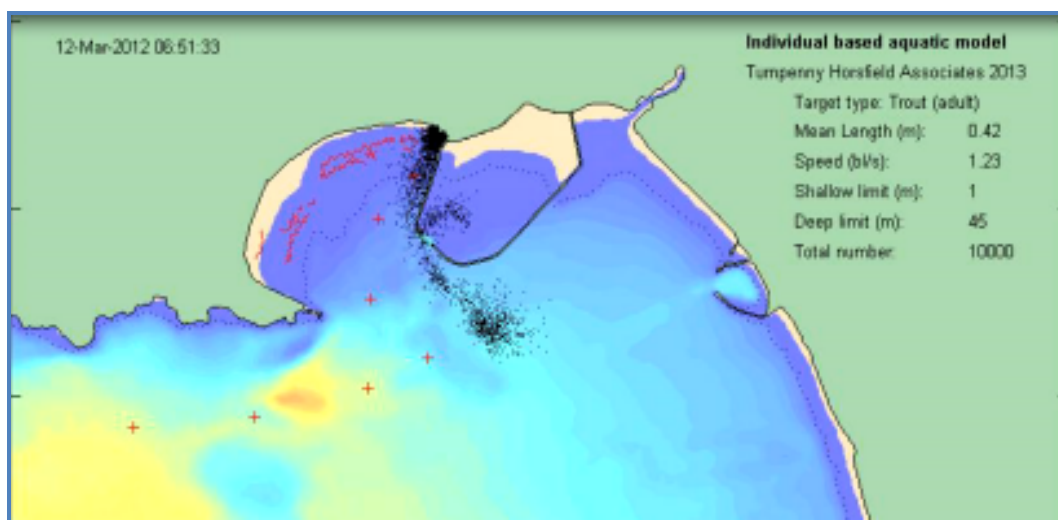


Figure 9.17 Section of a still frame of video output showing sea trout adult following olfactory trail into the R. Tawe. The increased entrainment into the Lagoon when compared with salmon can be seen.

- 9.5.3.42 Eels and lamprey are weaker swimmers than salmon and trout but are thigmophilic (i.e. they like to be in contact with stationary physical objects such as the seabed). This means they are capable of using selective tide stream transport, by resting on the bed when the tide is flowing a direction in which they do not wish to travel, and lifting up into the water column when the tide is flowing in their preferred direction of travel (incoming tide). This behaviour allows small (and therefore relatively slow swimmers) to move extremely quickly in a strong tidal system such as the Bristol Channel. Furthermore they are known to stay near the bed in daylight to avoid predation. The model fish exhibit this suite of behaviours and navigate to the nearest freshwater trail rather than a particular river. These models show how these simple behaviours are remarkably effective for these animals. Figure 9.18 is a still-frame of glass eels approaching from the West and entering the rivers Tawe and Neath; a degree of entrainment is seen in glass eels attempting to locate the Tawe river mouth. Olfaction is modelled in all species.

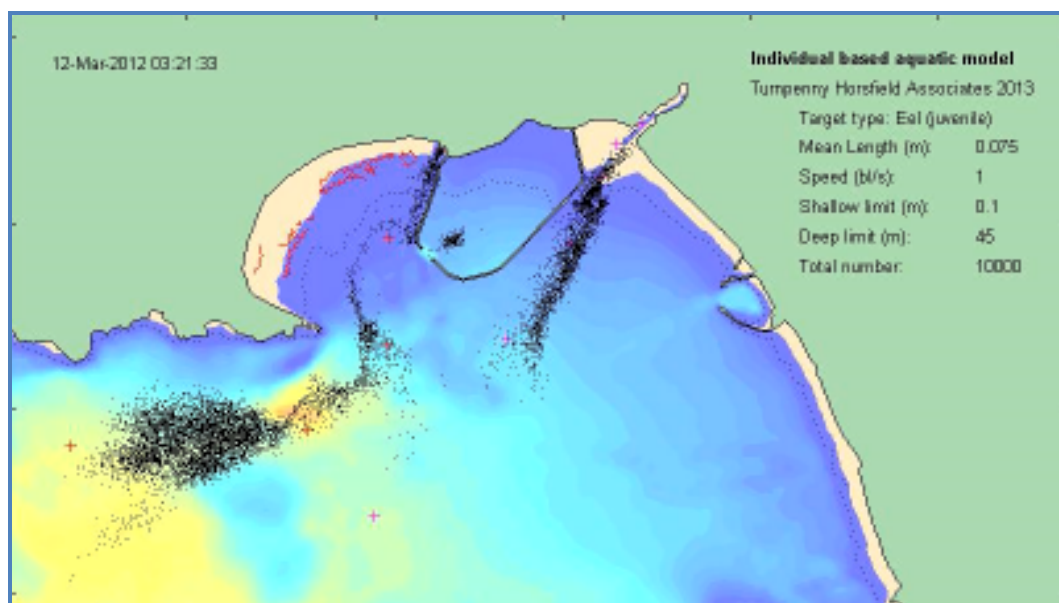


Figure 9.18 Section of a still frame of the video output for juvenile eels swimming to R. Tawe and R. Neath. The eels are small, swim weakly but use flooding tides to carry them toward the freshwater, and rest during ebb tides by moving close to the bed, and during daylight. Some eels have been advected into the Lagoon through the turbines and sluices.

- 9.5.3.43 Sea lamprey and river lamprey differ in the models in two respects. First, river lampreys tend to be smaller and therefore have lower swimming performance, which puts them at higher risk of entrainment into the Lagoon. Secondly, whereas river lamprey remain mainly in estuarine waters close to the river mouth, sea lampreys disperse much more widely into the marine environment forming panmictic populations that probably seek out the nearest convenient river when the time comes to spawn (Maitland, 2003). This means for river lamprey, any impact will be borne by local river stocks only, whereas for sea lamprey, the impact is likely to be spread across a regional stock (e.g. Bristol Channel).
- 9.5.3.44 Bass of juvenile and adult lifestages ('school bass') are seasonally resident in Swansea Bay. Adult school bass are strong swimmers and favour areas of fast current flow to feed on pelagic fish carried on the tide. They can often be seen in feeding schools at cooling water inlets, as well as at warm-water outfalls of power stations, but are seldom entrapped (Pickett & Pawson, 1994). It is expected that school bass will take advantage of the flow in and out of the tidal Lagoon to feed upon small pelagic fish such as sprat and herring; these smaller fish may in turn be feeding upon planktonic invertebrates arriving with the flow. Modelling has not been carried out for "school" bass lifestage.
- 9.5.3.45 Juvenile bass arrive inshore in early summer as small fry and spend their first year in inshore coastal and estuarine waters, moving into deeper water in the autumn or winter when marginal areas become too cold for them (Pickett & Pawson, 1994). In Swansea Bay they use the shallow water in the intertidal zone during an incoming tide, dispersing into deeper water on the ebb and avoiding being washed up on the beaches. The initialisation of the model in this case places the virtual fish uniformly randomly distributed in water of the appropriate depth range for the size class (age) and simulates the movement patterns during the tides. As they tend to follow the tidal margin down the beaches and then back towards their starting position, juvenile bass within the Lagoon are shown by the model to avoid areas near the turbines and sluices and are therefore at little risk of entrainment. As they move out to deeper water in

autumn/winter, they will pass through the sluices or turbines. Figure 9.19 shows a still-frame from the bass model.

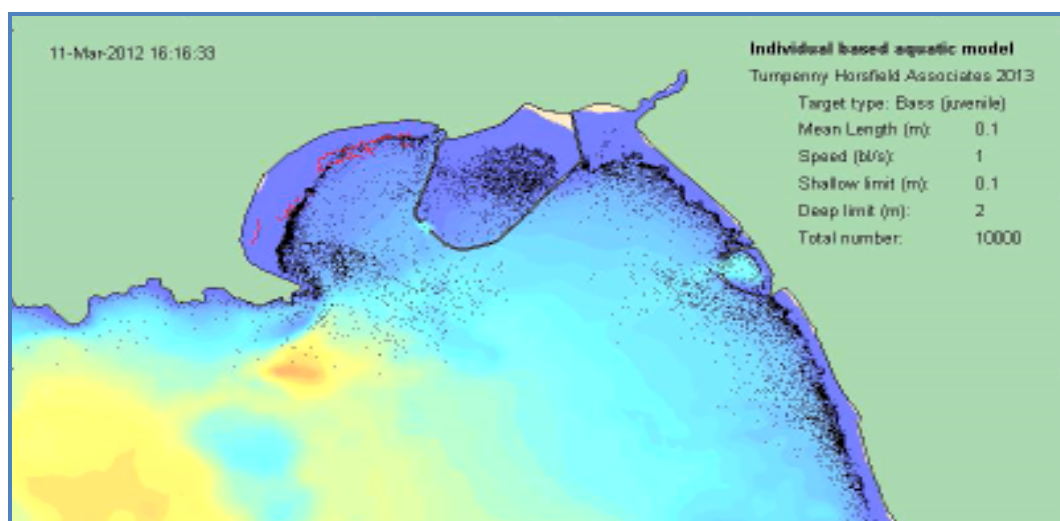


Figure 9.19 Section of a still-frame of the video output for the juvenile bass model. Juveniles exploit the intertidal shallow water on an incoming tide and disperse on the ebb. In general they swim in a way that avoids them being ejected from the Bay although the tides are strong. In the model the fish navigate toward the appropriate depth areas by returning to a similar position in which they were initialised to simulate habitat fidelity.

- 9.5.3.46 There are three known herring spawning grounds within the Bay, only one of which will be directly affected by the Lagoon. The relative proportions that spawn in the various parts of Swansea Bay are unknown. The IBM only represents the portion of the herring population that targets spawning substrates within the Lagoon and thus does not consider use of the alternative spawning grounds within the Bay. The results therefore present the worst case scenario, assuming the herring are targeting a single spawning site within the lagoon boundary. In addition the position of the “target” point for the model (red cross) is central to the lagoon beach as opposed to being located further west, more centrally within the historic spawning ground (see Figure 9.12), which in reality may result in an increased number of fish avoiding the turbines and accessing spawning grounds to the west of the western landfall. Spawners targeting sites within the Lagoon are therefore expected to pass through the sluices and turbine housing as shown in the model (Figure 9.20). They are likely to remain there until spawned and then leave the Lagoon. It should be noted that it is likely that a certain proportion of herring entering the Bay to spawn will not be affected at all, and instead head to one of the alternative spawning sites (Blackpill and Tawe Port).

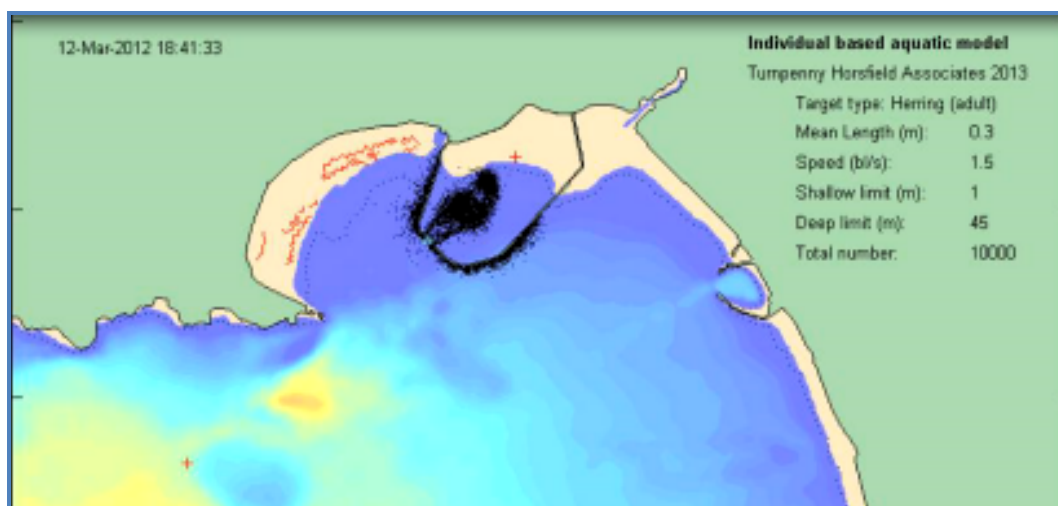


Figure 9.20 Section of a still-frame of the video output for the adult herring, with mass ingress of spawners into the Lagoon. The model shows others spreading along the Western and Eastern arms of the outer Lagoon wall.

- 9.5.3.47 Juveniles of plaice and other flatfish, as well as sandeel, which similarly occupy the intertidal/subtidal shallows, are modelled in a similar way to bass, but as an epibenthic species, their behaviour is moderated by the substrates in the Bay. If they are over a particular sediment, the model fish will either arrest their movement by attaching to the bed or swim in a random direction (in search for a different substrate). The model fish also perform similar activities to find their preferred depths. The still-frame view in Figure 9.21 is from the plaice model and leads to broadly similar conclusions as for bass.

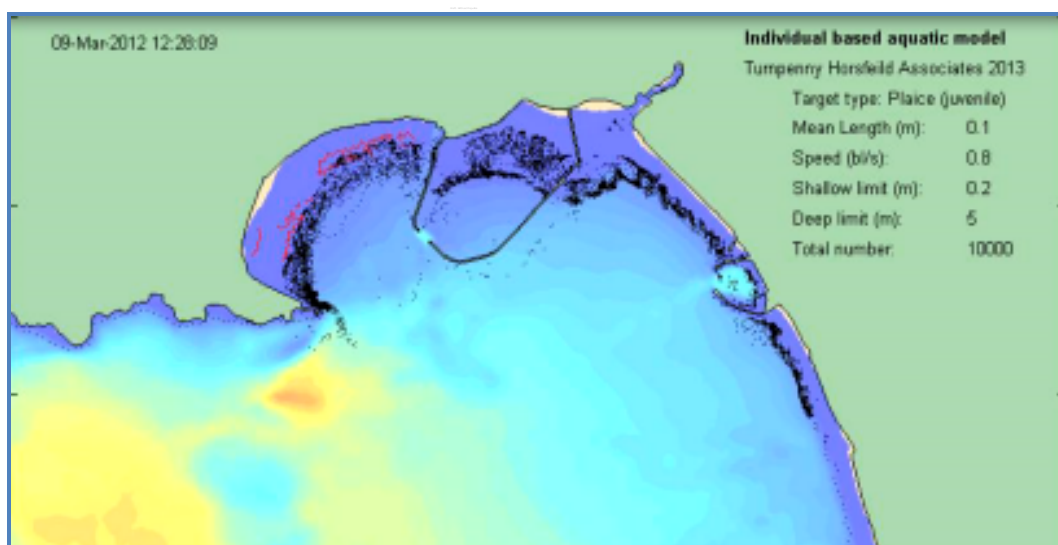


Figure 9.21 Section of a still-frame of the video output for the plaice model. Juveniles exploit the intertidal shallow water on an incoming tide and disperse on the ebb. They search out and embed themselves in fine substrates, which avoids them being ejected from the Bay although the tides are strong. As with bass, in the model the plaice navigate toward the appropriate depth areas by returning to a similar position in which they were initialised to simulate habitat fidelity.

Fish injury mechanisms in tidal power turbines

- 9.5.3.48 This section presents the turbine encounter rates generated by the IBM models for individual species and lifestages. Mortality rates associated with turbine encounters are outlined.
- 9.5.3.49 It should be noted that tidal power turbines that extract potential energy from tidal height differences across a barrage or Lagoon wall, differ from hydrokinetic turbines that extract energy from a tidal stream. Research in this field related to hydrokinetic turbines, is not generally applicable to barrage or Lagoon schemes. The review presented below is based only on studies relevant to the latter type of scheme and presents the key information used in the STRIKER™ v.4 turbine fish passage injury model.
- 9.5.3.50 The turbines selected for the Project are double-regulated horizontal axial-flow bulb turbines (Figure 9.22). The turbines will operate in both ebb and flow generation modes but will be optimised (facing into the impoundment) for ebb generation. During flood generation, the runner blades will rotate so that the leading edges continue to face the incoming flow. However, generating efficiency will be lower during flood-tide generation. Further details are provided in Chapter 4: Project Description.

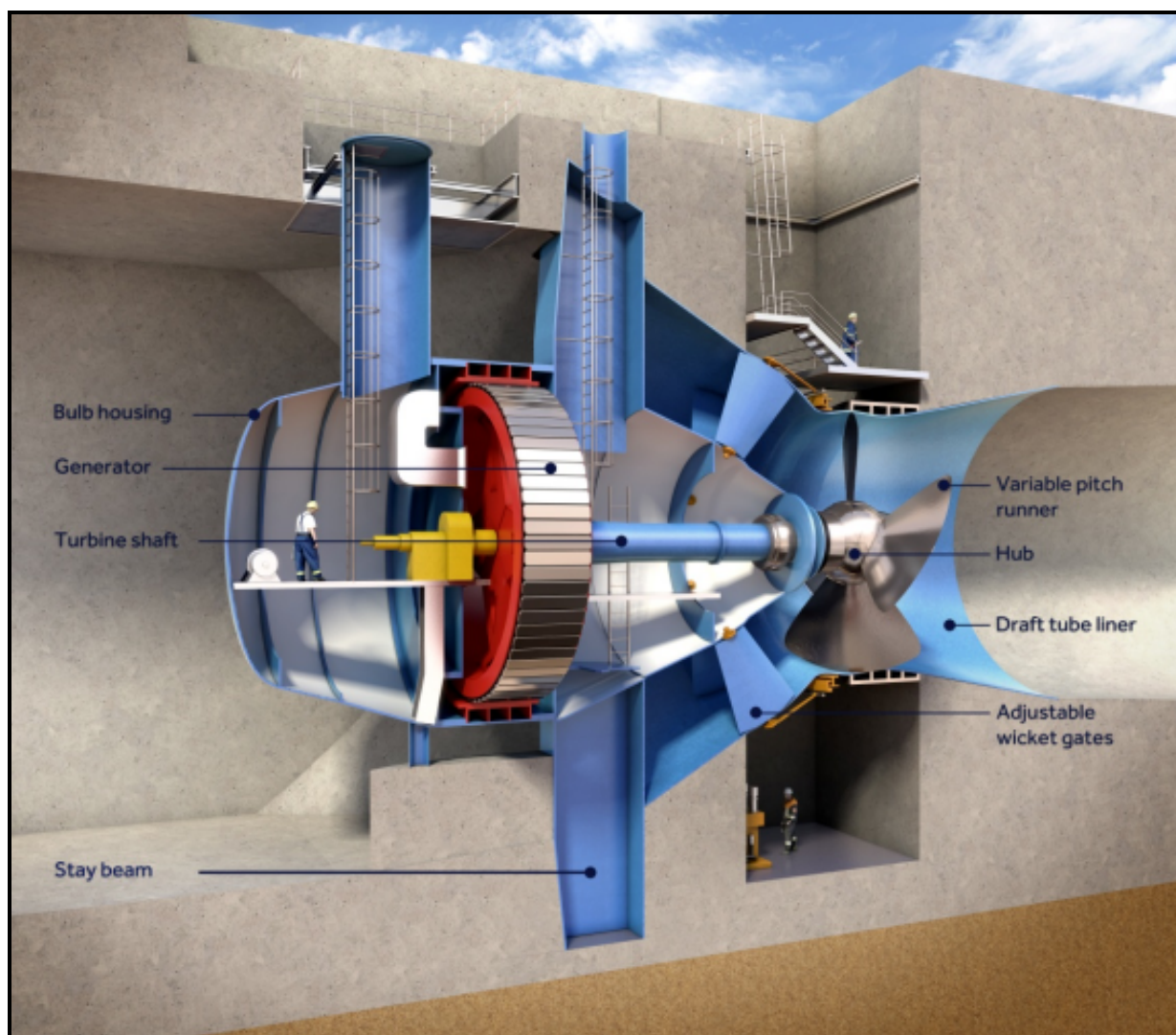


Figure 9.22 Illustration of axial flow turbine showing the main elements.



9.5.3.51 The turbines are taken to have the following design characteristics (see Chapter 4: Project Description); a worst-case value has been taken for rotation rate:

Turbine type.....	axial-flow bulb turbine
Attitude.....	horizontal axis
Runner diameter.....	7.0 m
Hub diameter.....	2.31 m
Number of blades.....	3
Rotation rate	67 rpm (maximum)
Regulation.....	double-regulated
Fish-friendly features.....	minimum gap runner
Draft tube submergence.....	-7m chart datum

9.5.3.52 The turbine operating modes are as follows:

- i. Ebb tide generation, in which flow passes through the turbine in the optimum direction: guide vanes → runner → draft tube. Turbine efficiency is within the range 80-90 % over most of the operating range.
- ii. Flood tide generation, in which flow passes through the turbine in the reverse direction: draft tube → runner → guide vanes. Turbine efficiency is lower under this condition (~70-80 %).
- iii. Sluicing. During periods around high and low tides when the sluices are opened to fill or drain the tidal Lagoon, water will also be allowed to sluice through the turbines. Under this condition the guide vanes will be fully open and the runners will free-wheel.

9.5.3.53 Strike injuries can occur when a fish collides with the fixed elements of the turbine water passages, including guide vanes (wicket gates), stay vanes or with the rotating turbine runner blades, at sufficient velocity. The likelihood and extent of injuries depends on the velocities involved and the shape of the blade's leading edge (Turnpenny et al., 1992).

9.5.3.54 The variables affecting the probability of a fish striking a runner blade were identified by (Von Raben, 1957), who developed the first equations for predicting probability of strike. Important physical variables identified were the length of the fish, the geometry and number of blades in the turbine runner, the rotational speed of the runner and the discharge through the runner. Later work by Monten (1985) considered the effect of velocity of impact on risk of fish injury, which is related to the relative velocity of the runner blade to that of the fish. The relative impact velocity is also a function of the location along the blade where impact occurs, with impact velocity increasing as radial distance along runner blades increases from a runner blade's hub to its tip. In a more recent investigation, Kibel et al. (2009) have come up with a critical impact pressure of $2.5 \text{ kg}^{-1} \text{ cm}^2$, above which fish injury will usually occur. Impact pressures with turbine components other than the runner blade are normally low enough to discount injuries arising from contact with them, as impact velocities are lower and profiles are generally more rounded (thicker).

9.5.3.55 Carlson and Ploskey (2004) reviewed four papers describing variants on blade-strike models (Von Raben, 1957; Bell, 1991; Turnpenny et al., 2000; Pavlov et al., 2002) and found that they were all essentially mathematically the same; therefore it is not necessary to consider the merits of alternative models.



- 9.5.3.56 Von Raben (1957) presented injury risk due to runner blade strike mathematically as follows:

$$\text{Injury Rate} = L * M/W$$

Equation 3,

where L is the water-length, calculated as:

$$W = U_{axial} / \cos \alpha (n * s/60)$$

Equation 4,

and n is the number of runner blades, s the rotational speed in rpm, and **U_{axial}** is the axial water velocity, calculated as discharge/runner swept area. The angle α is that formed between the streamlines and the axis of the turbine at runner's leading edge. The term **M** is a factor that takes account of the fact that, at some points on the fish's body, the contact will be glancing (e.g. the tail flexes out of the way) and the fish will not be injured. For eels, Von Raben (1957) estimated **M** = 0.43. Broadening this concept, Turnpenny, (1998) showed by experiment that **M** is a variable, dependent on fish mass and hence, when moving in a flow, its momentum. Essentially, the fish's probability of blade contact is the result of the relationship between its momentum, which tends to make it continue towards the blade, and the drag force of the water, which tends to pull it around the blade. A small fish has a relatively high surface area to mass ratio and the drag force wins, pulling the fish around the blade; large fish, vice versa. An egg or newly hatched larva, as an extreme example, will not be affected by blade strike, and generally the probability of strike injury in fish fry is for this reason very low.

- 9.5.3.57 The above description assumes that fish approach the runner with their long axis aligned with the flow streamlines, which represents the worst possible case: any deviation from this alignment would effectively reduce the 'apparent' length of the fish relative to the Water Length (Solomon, 1988), reducing strike probability. The relevant literature contains much discussion of the likely orientation of fish as they enter a hydroelectric turbine. Coutant and Whitney (2000) concluded that this behaviour is highly variable, depending on species, lifestage and other factors. In experiments where fish were released into turbine inlets, Deng et al. (2011) found that fish strike models gave the best fit to empirical data when any possible orientation of fish was assumed. Assuming random orientation is therefore the reasonable course, and has been adopted for the present assessment.
- 9.5.3.58 Observations of turbine-passed fish reported in a review by Eicher et al. (1987) indicate that strike-related injuries in Kaplan turbines increased with impact velocity; minimal mortality was seen at impact velocities of less than 12 ms^{-1} and observations indicated that impact velocities of 6 ms^{-1} or less would eliminate strike-related mortality. Experimental studies reported by Turnpenny et al. (1992) showed that collision velocities of less than 7 ms^{-1} with near-hub blade profiles in a bulb turbine would be unlikely to harm fish. Also working with salmonids, Alden Laboratories in the USA have developed relationships between survival and the fish length (**L**) and blade thickness (**t**) versus strike speed (Figure 9.23) which show an effect similar to that described by Kibel et al. (2009), except that in this case fish size is represented as length rather than body mass. STRIKER™ v.4 uses **L/t** ratios to compute injury risk from runner strike for four segments along the blade from hub to tip (Figure 9.24).

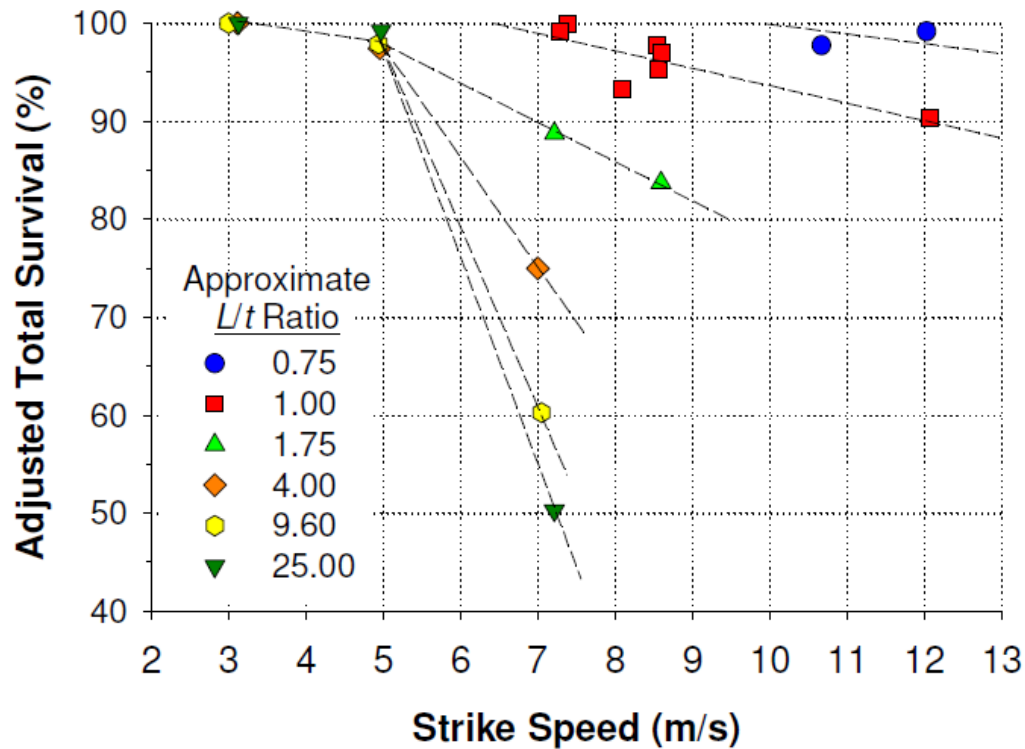


Figure 9.23 Blade strike survival rates of rainbow trout *Oncorhynchus mykiss* tested at various fish length to leading edge thickness ratios (L/t) over a range of strike velocities (Alden Labs, undated).

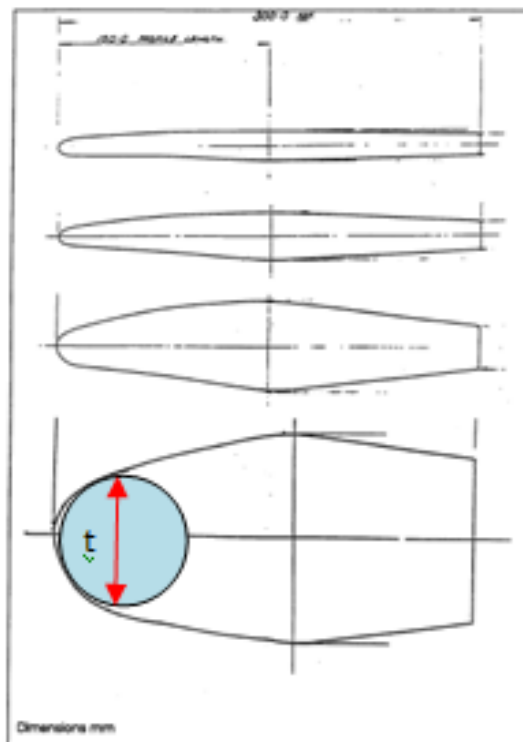


Figure 9.24 Runner blade profiles from tip (top) to hub (bottom) (Turnpenny et al., 1992). Blade thickness, t , is measured as the diameter of the circle (shown in blue) best fitting the tip profile.

- 9.5.3.59 Fish are subjected to a sequence of pressure changes as they pass through a turbine. Pressure effects are relatively small in tidal power turbines owing to the low operating heads (≤ 5.5 m for Swansea) compared with many onshore hydroelectric schemes that rely on elevation. The typical pattern is illustrated in Figure 9.25. A 1.0 bar change in pressure is equivalent to a 10 m change in immersion depth. Depending upon its starting level in the water column, a fish may be initially drawn down towards the turbine entrance, which increases the hydrostatic pressure (phase 1). As it crosses from the upstream to downstream side of the turbine runner (phase 2), it experiences a hydrostatic pressure drop equivalent to the head difference across the turbine. However, additional pressure change effects in phase 2 arise from (a) the rotation of the water as it passes through the turbine (swirl) and (b) hydrodynamic changes associated with fluid flow across the guide and stay vanes and turbine runner blade.
- 9.5.3.60 In addition to hydrostatic pressure changes, hydrodynamic pressure changes occur as a result of low-pressure areas that develop in the wake of guide and stay vanes and the runner blade. Fish passing close to the blades or structures may enter these zones and experience sudden severe pressure drops.
- 9.5.3.61 Phase 3 represents passage through the draft tube and return to the water body on the downstream side of the turbine. Pressure changes here result from a combination of swirl, large scale water turbulence and exiting of fish into the free water column.

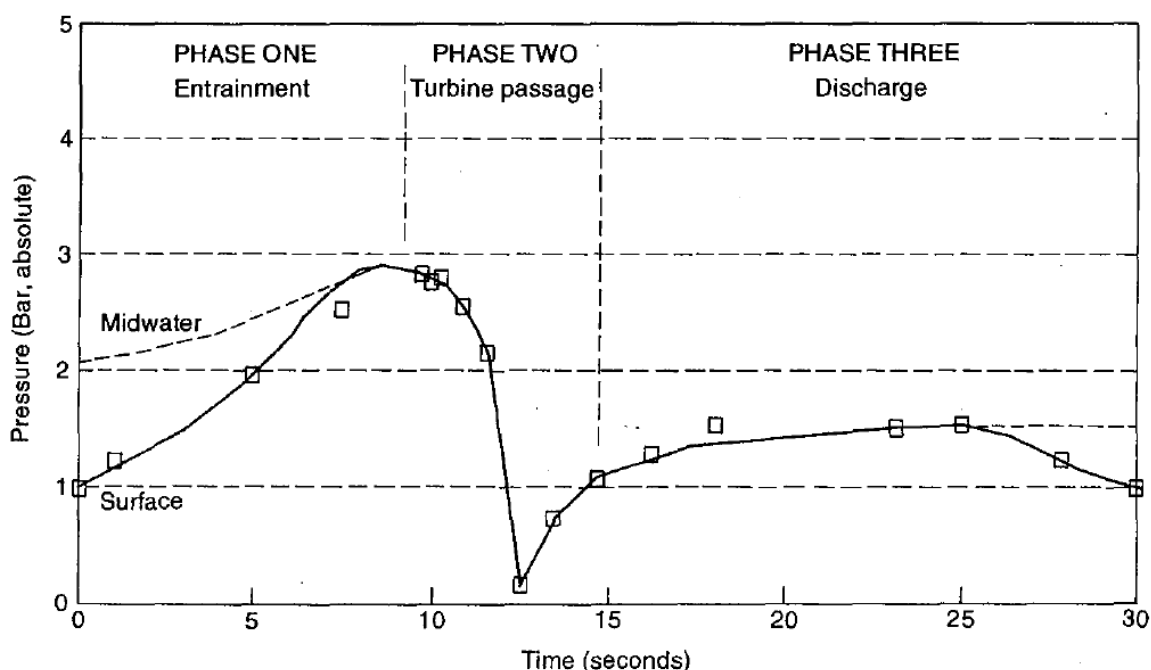


Figure 9.25 Typical pressure time-series representing passage of a fish through a tidal-power turbine. This is known as the 'meanline curve' (Turnpenny, 1998).

- 9.5.3.62 Considering pressure reduction effects on swimbladders, fish can be divided into the following categories:
- Fish without swimbladders (e.g. elasmobranchs, lampreys, mackerel) or with non-functional vestigial swimbladders (e.g. flatfishes);
 - Fish that regulate swimbladder volume by gulping air at the water surface or venting excess volume to the atmosphere via the gut (physostomes: e.g. herring, shad, salmon, sea trout);



- c) Fish that regulate swimbladder volume through vascular exchange (physoclists: e.g. cod, whiting, bib); and
- d) Fish with a hybrid vascular and venting system (physoclistostomes: e.g. eel).

9.5.3.63 Details of swimbladder types for fish modelled using STRIKER™ v.4 are shown in Table 9.16

9.5.3.64 Category (a) fish are exempt from swimbladder-related effects but can suffer from gas embolisms in the bloodstream, eyes and other organs. Fish in all other categories are subject to gas embolism effects but also to the effects of Boyle's law, i.e. a halving of external pressure will cause the swimbladder to double in volume with the potential to rupture it. This can affect buoyancy control and hearing sensitivity.

9.5.3.65 Čada et al. (1997) reviewed data on responses of physostomes and physoclists to rapid pressure change and this database was expanded by Turnpenny et al. (2000) using further data from Turnpenny and O'Keeffe (2005). Turnpenny et al. (1992) developed the following formulae to predict injury rates (I) which are used within the STRIKER™ v.4 model:

Physoclists	$I (\%) = -38.83 \ln (x) + 1.756$	Equation 5
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Physostomes	$I (\%) = -3.997 \ln (x) + 1.571$	Equation 6
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Where: $x = [\text{exposed pressure (Pe)} / \text{acclimation pressure (Pa)}]$.

9.5.3.66 The presence of herring spawning grounds within the Bay means that larval herring may be present as ichthyoplankton in the water column as they disperse more widely after spawning. The sensitivity to pressure change of the larval stages were not reported by Turnpenny et al. (1992) but Hoss and Blaxter (1979) investigated responses of larvae of this species to rapid pressure change in the context of passage through thermal power station cooling systems. They showed that rapid pressurization to 5 bar (equivalent to 50 m hydrostatic change) followed by rapid decompression to the initial pressure had no effect on larvae up to 20 mm in length. Larvae from 25–29 mm showed increased mortality over controls; still larger larvae did not. Larvae which survived the pressure treatment fed as well as controls. Blaxter and Hoss (1979) went on to show that larval stages were less sensitive to rapid pressure change than older lifestages. Pressure effect modelling for adult herring using the STRIKER™ v.4 model has therefore been taken as a worst case for larval herring.

9.5.3.67 Shear stress occurs in fluids across a velocity gradient. A fish that enters a velocity gradient is exposed to shearing forces across its body, which can lead to various forms of trauma, including scale and mucus loss from the body surface, injuries to exposed delicate organs, principally the eyes and gills (Turnpenny et al., 1992; Čada et al., 2007). Since turbulence results in the formation of vortices across which there may be strong velocity gradients, shear stress and turbulence are closely linked.

9.5.3.68 Turbulence occurs on different scales and these are important to the fish as illustrated in Figure 9.26. Small-scale turbulence (a) acts on particular delicate body parts such as skin and scales, eyes or gills; intermediate scale turbulence (b) can cause bending and torsion injuries; and large-scale turbulence (c) can displace and disorientate the fish.

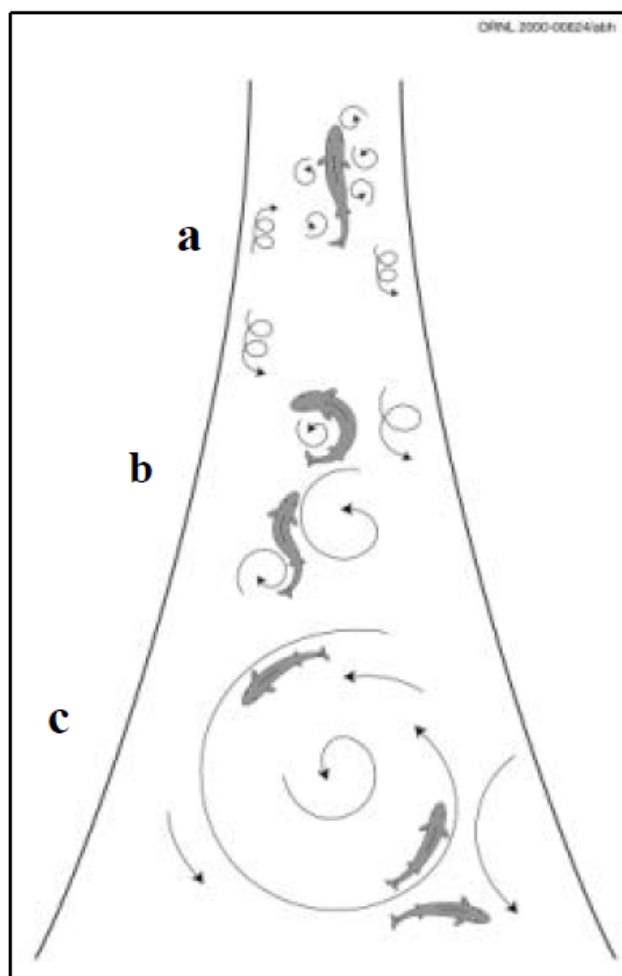


Figure 9.26 Different scales of turbulence and their effects in relation to fish size (Odeh et al., 2002).

- 9.5.3.69 Shear stress, like pressure, is a force per unit area, and has the same units, Newtons per square metre (Nm^{-2}); but whereas a pressure is directed perpendicular to a surface, shear stress acts parallel to the surface. In some studies, this effect is represented by another metric, the strain rate, defined as the mean change in water velocity over distance (e.g. Neitzel et al., 2000), as this quantity is more readily extracted from some computational programs. The present study considers shear stress rather than strain rate as the most relevant biological response data. For fish species occurring in Swansea Bay area, these are reported using this metric by Turnpenny et al. (1992).
- 9.5.3.70 Within a turbine, shear stress results from two effects: small-scale turbulence near the runner and small-to-large-scale turbulence in the section downstream of the runner (Čada et al., 1997). Generally the highest shear stresses occur where the relative velocity of water to turbine components is maximal, i.e. close to the runner. As relative velocities in the order of $20\text{--}30 \text{ ms}^{-1}$ are typical in flows near the blade tips, and the velocity at the blade surface is zero, the strongest gradients and most damaging shear stresses occur in these regions, with high levels in close proximity to the blades (Figure 9.27). Fish entering this high-shear-stress envelope around the blades are therefore at most risk of injury, the greatest concern here being from small-scale turbulence creating localised but intense shear stress pockets that cause the kinds of trauma listed above. This may be regarded also as the 'near-miss' zone for strike injury. As it only occupies a small proportion of the overall water passage through the turbine available for fish to pass (at least during high efficiency ebb flow generation), the probability of exposure to damaging shear stresses

while passing the runner is correspondingly small for all but delicate fish species. It can be computed using probabilistic statistics relative to a defined shear stress injury threshold.

- 9.5.3.71 When the turbine is operating in (sub-optimal) flood-generation mode, the volume around the runner in which high shear stress levels occur is likely to be higher owing to the poorer hydraulics, but the risk of shear-stress-related injuries will not necessarily be higher, as lower relative velocities between blade and water tends to limit the occurrence of more extreme shear stress values (McEwen & Scobie, 1992).

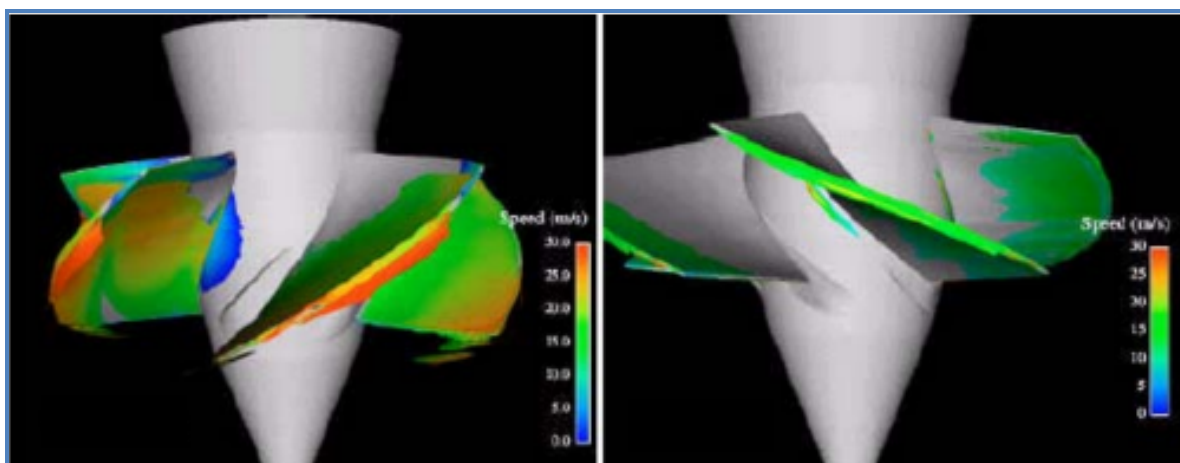


Figure 9.27 Damaging shear zones in Kaplan turbines (Garrison et al., 2002). The left hand plot shows a sub-optimal (low efficiency) condition, similar to what might be expected e.g. with flood-generation at Swansea.

- 9.5.3.72 The second area of potentially high shear stress is downstream of the blades, where turbulent wakes are generated. It is here that the larger scales of turbulence occur that can disorientate fish or cause torsion-related injuries such as spinal fracture in more extreme conditions (Čada et al., 1997). For the ebb-tide case, turbulent wake formation occurs within the draft tube, and for the flood-tide case within the turbine's normal intake section. Again, as the turbine will be operating more efficiently in the ebb-tide case, downstream flow will be less chaotic than in the flood-tide case.
- 9.5.3.73 Shear stresses will also be generated at other points in the turbine, around the guide and stay vanes and in proximity to the casing walls. However, as these components are static, the shear stress values will be much lower than those around the blades. Shear stress values around the blades during turbine sluicing will also be relatively low, as the hydraulic head during sluicing phases will limit water velocities through the turbines.
- 9.5.3.74 Biological responses to shear stress have been studied by a number of investigators using high-speed water jets injected into a still body of water to generate locally high shear stress levels, using variations on an apparatus originally described by Groves (1972). This creates intense, small-scale shear stress levels that can be used to simulate the damaging small-scale shear stresses occurring in turbines. The method was adopted in more than ten years of study in the US Department of Energy's (USDOE) "environmentally friendly" turbine programme, which established a shear stress fish injury threshold of 1600 Nm^{-2} , a value used as a guideline in fish-friendly turbine design in the USA (Čada et al., 2007). These authors calculated that only 0.6 % of fish passing through a large Kaplan turbine (the example given is Wapanum on the Columbia River, having a runner diameter of $\sim 7 \text{ m}$, similar in size to the proposed turbines for this Project) would be harmed by shear

stress. It should be noted that the damage criterion was derived only from research juvenile Chinook salmon *Oncorhynchus tshawytscha*. Findings more relevant to Swansea Bay are those reported by Turnpenny et al. (1992), who examined effects on a number of UK marine and estuarine fish species of shear stress levels ranging from zero to 3410 Nm^{-2} . From this, the USDOE criterion 1600 Nm^{-2} appears to be appropriate for species other than delicate clupeids. Shad and herring, on the other hand, are injured by shear stress levels as low as 206 Nm^{-2} .

Table 9.19 Effects of shear stress levels on fish in laboratory experiments reported by Turnpenny et al. (1992). Note: mortality data corrected against Control (zero shear stress) values.

Fish species	Shear stress level Nm^{-2}			
	206	774	1920	3410
Salmonids: Atlantic salmon, age 2-gp smolts.	No detectable effect.	No detectable effect.	Slight mucous and scale loss. 28% of fish with eye injury. 4 % mortality after 7 days (d).	Slight mucous and scale loss. 32% of fish with eye injury. 8% mortality after 7 d.
Salmonids: Brown trout, age 1-2 gp.	No detectable effect.	No detectable effect.	Slight mucous and scale loss. 10% of fish with eye injury. 20% mortality after 7 d.	Slight mucous and scale loss. 10% of fish with eye injury. 10% mortality after 7 d.
Clupeids: Herring, age 0-group.	Light mucous and scale loss. 100 % mortality within 1 h.	> 20 % mucous and scale loss per fish. Eye haemorrhage in 60 %. 100 % mortality within 1 h.	Average 58 % mucous and scale loss per fish. 60 % eye injury. 40 % with torn jaws/operculum. 100 % mortality within 1 h.	Average 90% mucous and scale loss per fish. 40-60% eye injury. 20 % with torn jaws/operculum. 100 % mortality within 1 h.
Clupeids: Twaite shad.	Not tested.	Not tested.	Not tested.	Average 90% mucous and scale loss per fish. 40% eye injury. 20% with torn jaws/operculum. 100% mortality within 1 h.
Flatfish: Sole.	Not tested.	No detectable effect.	Heavy loss of mucous. 65% mortality within 7d.	Heavy loss of mucous. 75% mortality within 7d.
European eel.	No detectable effect.	No detectable effect.	Some mucous loss. 7-d survival not affected.	Some mucous loss. 7-d survival not affected.
Percids: Bass.	Not tested.	Not tested.	Average 9% mucous and scale loss per fish. 13% with gill injury. 7% bleeding into body cavity. No survival data.	Average 10% mucous and scale loss per fish. 8% with gill injury. No survival data.
Gadoids: Whiting.	Not tested.	Not tested.	Average 5% mucous and scale loss per fish. 20% with eye injury. 20% with torn jaws/operculum. 100% mortality within 1h.	Average 5% mucous and scale loss per fish. 28% with eye injury.

9.5.3.75 Within the natural environment, fish are exposed to shear stresses associated with fast flowing water and bed features, turbulence around waterfalls, etc. Čada and Odeh (2001) reviewed records of naturally occurring shear-stress levels, which in streams and rivers

appear to seldom exceed a few tens of Nm^{-2} and only exceeded 2000 Nm^{-2} in the most extreme flash flood events in small basins. It is therefore unsurprising that most fish appear to be well adapted to cope with values of a few hundred Nm^{-2} . A notable exception are the clupeids (Table 9.19), which experiments have shown are susceptible to injury when exposed to even relatively low levels of shear stress of $\sim 200 \text{ Nm}^{-2}$. The pelagic habit of clupeid fishes such as shads (*Alosa alosa* and *Alosa fallax*) and herrings ensures that they normally avoid contact with the bed and other solid structures and therefore scale loss is avoided. An exception in their lifecycle is when they deposit their eggs on rocks or gravel spawning beds, immediately after which mortality in these fish can be naturally very high (Maitland & Hatton-Ellis, 2003).

- 9.5.3.76 Cavitation is sometimes identified as a cause of fish injury in turbines (Solomon, 1988). Cavitation is defined as the rapid vaporisation and condensation process in a liquid. In turbines it can occur mainly in the wake of the runner blades where local areas of reduced pressure arise near the blades, and in cavitating vortices shed by the blades. The collapse of vapour bubbles can sometimes be violent and cause noise, vibrations and pressure fluctuations. As this can cause pitting in the runner blades, turbine designers strive to ensure that cavitation does not occur. This is achieved by good hydraulic design, minimising areas of reduced pressure, and by submerging the turbine deep enough to maintain adequate hydrostatic pressure in the draft tube. (Čada et al., 1997) state that “turbine designs that minimise pressure reductions to no more than 60 per cent of ambient will not cavitate, and cavitation related injury to fish will not occur”. In the Project the turbines will be set at a level of - 7 m below Chart Datum to prevent cavitation and it is not expected that cavitation will be a significant source of fish injury.

Turbine fish injury modelling using STRIKER™ v.4

- 9.5.3.77 The injury risk associated with a single pass of a fish through a turbine was estimated for different species and lifestages of fish shown in Table 9.17 using the STRIKER™ v.4 turbine passage model, a dedicated tidal power version of the STRIKER™ v.1 model described by Turnpenny et al. (2000). STRIKER™ v.4 models: runner strike injury risk; effects of rapid hydrostatic and hydrodynamic pressure flux across the turbine runner; and effects related to hydraulic shear stress. The STRIKER™ models have been widely used in UK hydropower assessments and are based on stress-response relationships originally developed for a 9 m reference design horizontal axial-flow turbines similar in design to the 7 m turbines proposed for this Project (Turnpenny et al., 1992). A full report of the turbine passage modelling for STRIKER™ v.4 and the underlying assumptions is provided in Appendix 9.4 (Volume 3). The key results are given below.
- 9.5.3.78 Input data to STRIKER™ v.4 include key design parameters such as turbine runner size, number of runner blades and rotation rates, as well as variables such as flow rate, operating head and flow direction:

Fixed Turbine Parameters (all dimensions in mm except where stated)	
Rotation rate (rpm)	67
Turbine hub diameter (m)	2.310
Turbine runner diameter (m)	7.000
Number of turbine blades	3
Guide vanes present (1 = yes, 2 = no)	1

Variable turbine parameters	
Flow rate (cumecs) – set as appropriate for net operating head (below)	297
Ebb (set as 1) or flood tide (set as 0)	1
Net operating head (m)	5.0

- 9.5.3.79 Other proprietary information from turbine manufacturers on blade design pressure, turbulence and shear conditions within the turbine obtained by computational fluid dynamic (CFD) analyses (see e.g. McEwen and Scobie, 1992) are also provided to the program.
- 9.5.3.80 The STRIKER™ v.4 model integrates information over the full range of operating heads and in this case used frequency data shown in Figure 9.28 to weight fish injury rate predictions.

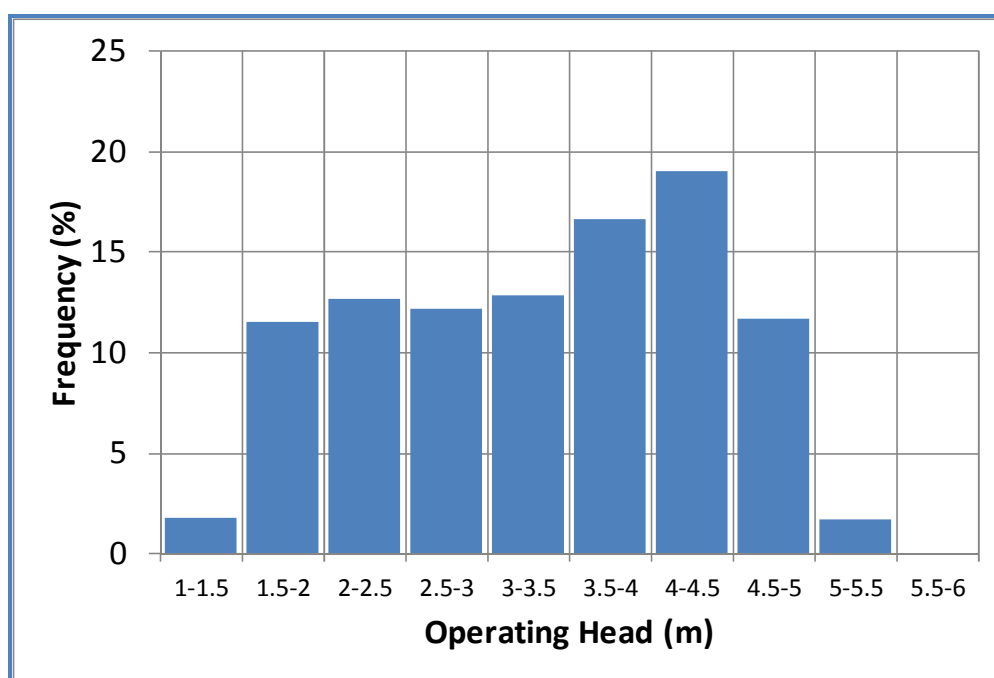


Figure 9.28 Frequency distribution of turbine operating head expected for the Project turbines.

- 9.5.3.81 Biological data entered into the program include fish species, population length-frequency distributions, fish fineness ratios (fish length divided by maximum body diameter), fish swimming speed and orientation. For the Project-specific assessment, fish orientation at the runner entry was assumed to be random and hence mean swimming speed relative to turbine flow defaulted to zero. Length-frequency distributions for fish were obtained from baseline survey data or relevant literature for the Bristol Channel/Severn Estuary region (Appendix 9.1 and Appendix 9.2, of Volume 3).
- 9.5.3.82 A sample output showing results for adult sea trout is shown below. The left hand column shows the range of fish lengths used. 'Swimming-Factor-Adjusted Length' is the 'apparent length' projected onto the turbine axis as described in Solomon (1988). The 'Mutilation Ratio' is the size-specific value **M** computed according to (Turnpenny, 1998). The next four columns give predicted injury rates caused by the separate effects of runner blade strike, shear stress and pressure change, and the compound value of all three effects together. The final two columns show the length-frequency distribution used and the length-weighted net mortality. The final figure in the bottom right-hand corner estimated mortality rate across all sizes. The example is for ebb flow generation

operating at a net operating head of 3.75 m. Average mortality rate over the whole tidal operating cycle is based on similar outputs for a series of operating heads, weighted according to the frequencies in Figure 9.28. Note that injury rates have been reported as mortality rates here, assuming that all injuries will be fatal.

Project Name:			Swansea Tidal Lagoon Scheme 7m Bulb Turbine					
Fish species:			Sea trout adult				Sea trout adult	
Operating Condition:			Ebb Tide	Net head=	3.75 m		Length-weighted mortality rate	
Discharge =			370.00	cumeecs	On design			
Fish swimming condition:		1	Fish swimming speed		0 bl/s			
Fish Length (cm)	Swimming-Factor-Adjusted Length	Mutilation Ratio	Predicted Injuries Due to:				Length-frequency	Net mortality
			Strike	Shear	Pressure	Compound		
35	23	0.56	4.1%	1.08%	0.33%	5.5%	8.0%	0.4%
45	30	0.60	5.7%	1.08%	0.33%	7.0%	21.0%	1.5%
55	37	0.63	7.3%	1.08%	0.33%	8.6%	50.0%	4.3%
65	44	0.65	9.0%	1.08%	0.33%	10.3%	19.0%	1.9%
75	50	0.67	10.7%	1.08%	0.33%	12.0%	2.0%	0.2%
85	57	0.69	12.5%	1.08%	0.33%	13.7%	0.0%	0.0%
Sea trout adult								8.4%

9.5.3.83 It will be seen from the sea trout example above that the predicted injuries are predominantly due to blade strike, with much lower contributions due to shear stress and pressure. This is the case for most of the species modelled. However, for the delicate clupeid species, shad and herring, low shear stress values will cause injury through scale loss and this factor becomes predominant as shown in the following table for herring. The predicted pressure-related mortality rate of 0.33 % has also been used as a worst case to assess effects on turbine passage of larval herring.

Project Name:			Swansea Tidal Lagoon Scheme 7m Bulb Turbine					
Fish species:			Herring				Herring	
Operating Condition:			Ebb Tide	Net head=	3.25 m		Length-weighted mortality rate	
Discharge =			360.00	cumeecs	On design			
Fish swimming condition:		1	Fish swimming speed		0 bl/s			
Fish Length (cm)	Swimming-Factor-Adjusted Length	Mutilation Ratio	Predicted Injuries Due to:				Length-frequency	Net mortality
			Strike	Shear	Pressure	Compound		
5	3	0.26	0.2%	47.84%	0.33%	48.1%	0.0%	0.0%
10	7	0.37	0.8%	47.84%	0.33%	48.4%	0.0%	0.0%
15	10	0.43	1.4%	47.84%	0.33%	48.7%	0.0%	0.0%
20	13	0.47	2.0%	47.84%	0.33%	49.1%	25.0%	12.3%
25	17	0.51	2.7%	47.84%	0.33%	49.4%	50.0%	24.7%
30	20	0.53	3.5%	47.84%	0.33%	49.8%	25.0%	12.5%
						Herring		49.4%

9.5.3.84 Table 9.20 and 9.21, each show ebb and flood generation cases respectively. Predicted mortality rates for the selected species and lifestages at different operating heads are shown; whilst flow-weighted values for the whole tidal operating cycle are given in the right-hand columns.

9.5.3.85 To estimate the fish mortality rates associated with turbine passage considering flood and ebb encounters, the above mortality rates per fish encounter were applied to the results of the encounter rate IBM for the individual species and lifestages. The calculations for $F' (\%) = P_{\text{encounter}} (\%) \times P_{\text{injury}} (\%)$ (Equation 2) were performed for each time a fish encountered the turbines within the model run and once a fish had been injured it was recorded and removed from subsequent iterations to prevent multiple accounting. This process was repeated 1000 times (in a process called bootstrapping) to estimate the mean and standard deviations of all the possible outcomes given the probabilities above and the pattern of fish encounters with the turbines.

9.5.3.86 Table 9.22 lists the encounter rates and associated mortality rates for the Project. The mortality rates are annual averages. The figures below represent unmitigated mortality rates. Further information is given on mitigation and residual impacts post mitigation in section 9.4.6.

Table 9.20 Predicted percentage fish mortality rates for a single pass of the turbine over operating head range, ebb tide generation

Species/ Lifestage	Tidal Condition: Ebb									
	Net Operating Head (m)									
	1.25	1.75	2.25	2.75	3.25	3.75	4.25	4.75	5.25	Full Tidal Range
Atlantic salmon & sea trout smolt	3.3%	3.2%	2.9%	2.9%	2.9%	2.8%	2.8%	2.8%	2.9%	2.90%
Atlantic salmon adult	11.2%	10.6%	9.1%	9.3%	9.1%	8.9%	8.9%	8.9%	9.0%	9.23%
Sea trout adult (Panteg trap)	10.5%	9.9%	8.5%	8.8%	8.6%	8.4%	8.4%	8.4%	8.5%	8.70%
Shad adult	51.1%	50.9%	50.4%	50.5%	50.4%	50.4%	50.3%	50.4%	50.4%	50.46%
Herring	49.8%	49.7%	49.4%	49.5%	49.4%	49.4%	49.4%	49.4%	49.4%	49.47%
Glass eel/elver	0.7%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	0.60%
Silver eel	7.0%	6.6%	5.6%	5.7%	5.6%	5.5%	5.4%	5.5%	5.5%	5.67%
Gadoids	9.8%	9.5%	8.9%	9.1%	9.0%	8.9%	8.8%	8.9%	8.9%	9.00%
Bass	5.2%	5.0%	4.7%	4.8%	4.7%	4.9%	4.7%	4.7%	4.7%	4.78%
Flatfish	2.2%	2.1%	1.8%	1.9%	1.8%	1.8%	1.8%	1.8%	1.8%	1.86%
Sandeel	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.28%
Lamprey	7.3%	6.8%	5.7%	5.9%	5.8%	5.6%	5.6%	5.7%	5.7%	5.86%

Table 9.21 Predicted percentage fish mortality rates for a single pass of the turbine over operating head range, flood tide generation

Species/Lifestage	Tidal Condition: Flood									
	Net Operating Head (m)									
	1.25	1.75	2.25	2.75	3.25	3.75	4.25	4.75	5.25	Full Tidal Range
Atlantic salmon & sea trout smolt	3.9%	3.8%	3.5%	3.5%	3.5%	3.5%	3.5%	3.5%	3.5%	3.52%
Atlantic salmon adult	11.8%	11.1%	9.6%	9.9%	9.7%	9.5%	9.5%	9.5%	9.6%	9.81%
Sea trout adult (Panteg trap)	11.1%	10.5%	9.1%	9.3%	9.2%	9.0%	8.9%	9.0%	9.1%	9.28%
Shad adult	46.6%	46.4%	45.8%	45.9%	45.9%	45.8%	45.8%	45.8%	45.8%	45.90%
Herring	45.2%	45.1%	44.8%	44.8%	44.8%	44.8%	44.7%	44.8%	44.8%	44.82%
Glass eel/elver	0.7%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	0.60%
Silver eel	7.0%	6.6%	5.6%	5.7%	5.6%	5.5%	5.4%	5.5%	5.5%	5.67%
Gadoids	11.3%	11.0%	10.4%	10.5%	10.5%	10.4%	10.3%	10.4%	10.4%	10.50%
Bass	5.2%	5.0%	4.7%	4.8%	4.7%	4.9%	4.7%	4.7%	4.7%	4.79%
Flatfish	2.2%	2.1%	1.8%	1.9%	1.8%	1.8%	1.8%	1.8%	1.8%	1.86%
Sandeel	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.28%
Lamprey	7.3%	6.8%	5.7%	5.9%	5.8%	5.6%	5.6%	5.7%	5.7%	5.86%

9.5.3.87 Turbine passage impacts on shellfish have not been modelled. Adult shellfish are not likely to become entrained in the generating flow as they are generally attached to, or beneath, the substrate. The larval stages of shellfish, such as mussels and oysters are pelagic but their small size and mass, makes them likely to follow the flow streamlines around the blades, avoiding injury (Turnpenny, 1997; Wilson et al., 2007).

Table 9.22 Combined results of IBM Encounter Model and STRIKER™ v.4 Fish Injury Model. In all cases sample size n=10,000. Mean mortalities are calculated by applying the probabilities of injury through the turbine passes from the STRIKER™ v.4 model, dependent on tidal state and direction of flow, and predicted encounter/ multiple-passage rates from the IBM Encounter Model.

Species	No. of fish Encountering turbines	Mean Repeat No. of Turbine passes	Overall Turbine Entrainment Injury Rate	
			mean %	standard error %
Atlantic salmon adult	603	1.65	0.87	0.09
Atlantic salmon smolt	125	2.98	0.12	0.03
Sea trout adult	2044	1.91	3.40	0.19
Sea trout smolt	149	3.38	0.16	0.04
Shad	56	4.30	0.77	0.08
Herring adult	6368	1.42	26.69	0.34
Eel adult	223	1.64	0.19	0.04
Eel elver	393	3.27	0.07	0.03
River Lamprey adult	999	2.68	1.35	0.11
River Lamprey transformer	120	3.33	0.02	0.02
Sea Lamprey Adult	1399	3.14	1.86	0.13
Sea Lamprey transformer	101	3.40	0.15	0.04
Bass adult	1186	3.69	0.27	0.01
Bass juvenile	1702	1.16	0.27	0.01
Plaice juvenile	38	4.76	0.69	0.01
Sandeel	41	3.93	0.01	0.01

Fish modelling for designated sites

- 9.5.3.88 The cases described so far relate to modelling the movements of fish within the Bay. The impact assessment is required to take into consideration wider effects of the scheme on the integrity of European protected sites (SPAs and SACs) that might be affected through effects on connectivity. The European sites considered to be within the scope of the Project include the Severn, Wye and Usk SAC, Carmarthen Bay SAC and the Pembrokeshire Marine SAC (including the Cleddau rivers). As the Pembrokeshire Marine SAC is located at ca. 118 km from the Project and there are no primary features pertaining to migratory fish, this designated site was not considered further. The Cleddau River SAC, comprising the Eastern and Western Cleddau Rivers, is located at ca. 81 km from the Project. A primary reason for the selection of this site is its population of river lamprey. Although river lamprey are diadromous, their fidelity to the estuaries of their natal rivers and nearby coastal waters means that they typically spend their entire life-cycle within or in proximity to the mouth of the rivers in which they spawn (Maitland, 2003). Consequently, this species, where it forms a feature of designated SACs (i.e. Carmarthen Bay, Rivers Usk, Wye, Severn and Pembrokeshire Marine SAC), has not been carried forward into screening for potential impacts, owing to the remoteness of SACs from Swansea Bay.
- 9.5.3.89 Salmon from the Severn, Usk and Wye are modelled only insofar as they are likely to come within the influence of flow circulation in Swansea Bay. This has been modelled by introducing an olfactory cue into the East-to-West moving (flood) tide and applying the same fish behaviour rules as for the local river stocks. Details of the assessment are presented in Appendix 9.3 (Volume 3) and also incorporated within the Habitats Regulation Assessment (HRA) Report, which accompanies the application for development consent (TLSB, 2014).
- 9.5.3.90 For the Rivers Wye and Usk, modelling predicts that mortalities for adult and juvenile salmon will be 0.03 and 0.01 % respectively. Juvenile salmon naturally incur significant



mortality during their emigration from natal rivers, whilst adult salmon are less predated upon. These projected losses are well within the bounds of natural variability, and are therefore not considered significant in relation to the overall population of the rivers. In relation to sea lampreys for the Rivers Wye and Usk, the Project will not have any effect on spawning habitat, it may however have a limited impact on returning adults and thus recruitment. Modelling indicates that adult sea lampreys are likely to incur low mortality as a result of the project (0.23 %). The loss to the population, resulting from the Project, will be within natural parameters, and thus the overall conservation objectives will not be affected.

- 9.5.3.91 Allis and twaite shad are not indigenous to the Tawe or Neath rivers and occasional individuals of twaite shad *Alosa fallax* caught in Swansea Bay are likely to be strays from the Usk, Wye and Severn spawning populations. Like salmon and sea trout, shads (*Alosa alosa* and *Alosa fallax*) home to natal rivers (Rulifson and Dadswell, 1987; Maitland and Hatton-Ellis, 2003) suggesting they follow olfactory trails. To assess potential interaction of Severn, Usk and Wye shad with the Project, the same modelling approach has been used as for the Severn, Usk and Wye salmon, although using appropriate size and swimming speed data for these species. For the Rivers Wye and Usk, the spawning distribution of twaite and allis shad will not be affected by the project owing to the distance of the Project from the rivers. Modelling indicates that adult sea lampreys are likely to incur low mortality as a result of the project (0.15 %).
- 9.5.3.92 For the River Severn SAC, the Project is not projected to impact on any of the conservation objectives of the River Severn SAC. The Lagoon may have some impact on the overall movement of lamprey and shad within the Severn Estuary. However, it is not considered that this will impact the long term sustainability of the population. It should be noted that the project is not a barrage, and as such it is not deemed a total exclusion barrier to any river. The abundance of prey species for both of these fish populations is likely to increase as a result of the Lagoon. Typically, renewable energy structures increase habitat heterogeneity and production (Jensen, 2002). The overall projected impacts on conservation objectives for the R. Severn SAC are therefore not deemed significant.
- 9.5.3.93 The assessment of the distribution and behaviour of diadromous fish species presented in Appendix 9.3 (Volume 3) and the mitigation measures that will be implemented (e.g. use of acoustic fish deterrents - AFDs), mean that the potential effects of the Project on populations of Atlantic salmon and shad species from SACs within the study area do not constitute a likely significant impact or threat to conservation objectives.
- 9.5.3.94 Owing to poor hearing sensitivity and therefore expected low effectiveness of AFDs in deflecting sea lamprey and the overall lack of knowledge regarding their marine movements, there is some potential for individuals of sea lamprey straying from SACs remote from Swansea Bay to be impacted. Nevertheless, the relatively small numbers of individuals involved, the low mortalities associated to turbines and their non-shoaling behaviour, mean that the likely effect would be limited.
- 9.5.3.95 Impacts from the project will be relatively localised (e.g. noise pollution, suspended solids, artificial lighting). Given the migratory range of the species being assessed, the overall sustainability of diadromous fish populations will not be affected.

The above conclusions also apply with respect of cumulative effects with other activities and projects within the study area.

***Variable-speed turbine option***

- 9.5.3.96 The above STRIKER™ v.4 analysis is based on the assumption that fixed-speed turbines will be used. The use of fixed-speed turbines is currently standard in all large hydropower schemes and is due to the need to produce alternating current at a fixed frequency to match the distribution grid frequency (50 Hertz in the UK). Variable duty in a fixed speed turbine is achieved by regulating the blade angles of either or both of the turbine runner and guide vanes.
- 9.5.3.97 This use of fixed speed turbines has two potential effects with regard to the safety of fish passage. First, as the water flow through the turbine reduces at the same time as operating head decreases, the axial velocity of water through the turbine becomes slower but the blade speed remains the same. This means that the water-length (described above) reduces and therefore that the probability that a fish will be struck by the blade increases towards lower flows. Second, as the blade angles change, the turbine moves away from its most efficient operating point, hence efficiency reduces and more turbulence, hydrodynamic pressure change and shear stress is generated, potentially creating more harmful conditions for fish.
- 9.5.3.98 Variable speed turbines are now under development to overcome these issues. Variable-speed turbines are matched to distribution grid frequency either by using variable speed gearboxes or using electronic inverters. In a variable-speed turbine the converse of the above with regard to fish is true. First, as the water flow reduces, the blades slow proportionately so that the water-length remains constant. Secondly, the water-to-blade angle remains constant so that efficiency is maintained.
- 9.5.3.99 It is not known whether variable-speed turbines will have been developed to a sufficiently advanced stage to become viable within the timeframe of the TLSB project. However, preliminary STRIKER™ v.4 runs have been undertaken to assess the potential benefit to fish, should they be available and selected for the Project. Table 9.23 shows predicted fish injury rates for a variable-speed turbine, compared with those for the fixed speed 67 rpm option. This shows potential reductions in ebb generation fish injury rates ranging from a lower value of around 1-2 % for shad and herring, up to around 36 % for shad and lamprey, and around 30 % for adult salmon and sea trout. Benefits on flood generation are slightly reduced, except in the case of shad and herring. The design appears to be slightly worse (2.8 %) for gadoids on flood generation. No Computational Fluid Dynamics (CFD) modelling data are as yet available from which to assess the effects of improved internal hydrodynamics, but this could yield further benefits for some species., notably the clupeid species for which this represents the largest source of trauma.

Table 9.23 Predicted percentage fish injury rates using STRIKER™ v.4 over full operating head range variable speed for variable-speed turbine option. Note: this models strike-related injuries for a 7 m axial flow design, but assumes the same internal hydrodynamic conditions as the fixed-speed option as no CFD modelling data are yet available for this version.

Species/Lifestage	Ebb Generation			Flood Generation		
	Variable Speed	Fixed Speed 67rpm	Change in Injury Rate	Variable Speed	Fixed Speed 67rpm	Change in Injury Rate
Atlantic salmon & sea trout smolt	2.29%	2.9%	-19.0%	2.96%	3.52%	-15.9%
Atlantic salmon adult	6.30%	9.23%	-31.7%	7.11%	9.81%	-27.5%
Sea trout adult	6.10%	8.70%	-29.9%	6.89%	9.28%	-25.8%
Shad adult	49.52%	50.46%	-1.8%	44.95%	50.45%	-10.9%
Herring	48.89%	49.47%	-1.1%	44.23%	49.44%	-10.5%
Glass eel/elver	0.47%	0.60%	-20.9%	0.48%	0.60%	-20.0%
Silver eel	3.54%	5.67%	-35.7%	3.68%	5.50%	-33.1%
Gadoids	7.53%	9.0%	-15.7%	9.15%	8.94%	2.3%
Bass	3.93%	4.78%	-17.0%	4.01%	4.74%	-15.5%
Flatfish	1.25%	1.86%	-31.4%	1.29%	1.82%	-29.2%
Lamprey	3.66%	5.86%	-35.9%	3.80%	5.70%	-33.3%

Option to reposition the turbine house

9.5.3.100 The IBM encounter model and hence turbine fish injury estimates presented above are based on the turbine house being positioned at Location A in Figure 9.29. As described in Chapter 4 Project Description, micro-siting the turbine and sluice gate housing may result in it being repositioned based on suitability of ground conditions. A likely location is the more seaward position shown as Location B, although a position between the two could also be adopted. At present these alternative locations have not been modelled in relation to IBM or STRIKER™ exercises but it can be expected that for most fish species there would be no material difference in effect. In the case of salmon and sea trout entering the R. Tawe as adults, turbine discharges from a more seaward point would be separated further from the olfactory trail emerging from the Tawe. For smolts exiting the Tawe, the risk of entrainment into the Lagoon would be expected, if anything, to be reduced. Thus the potential worst case scenario for the position of the turbine and sluice gate house has been assessed.

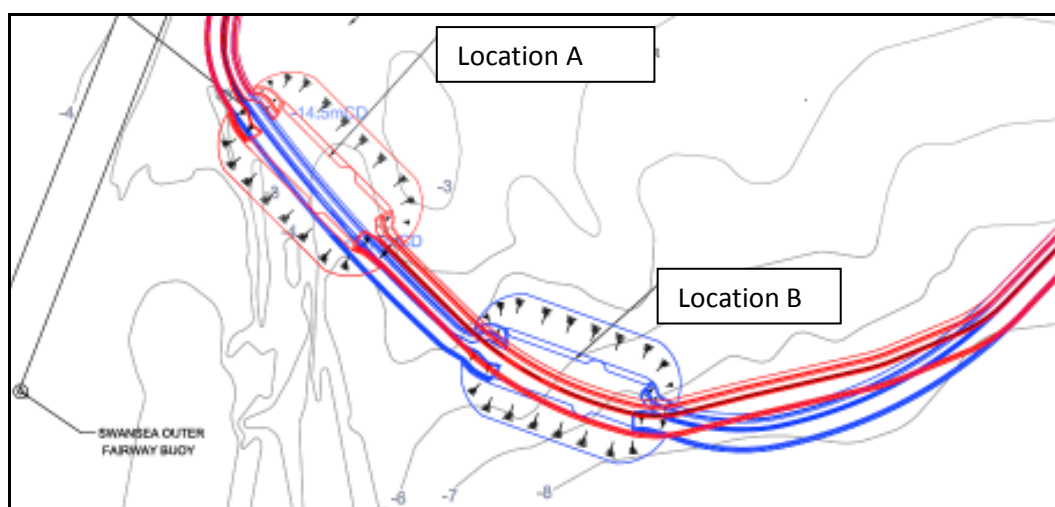


Figure 9.29 Two main alternative turbine and sluice gate housing locations



Comparison with findings from La Rance Tidal Power Scheme

- 9.5.3.101 La Rance tidal power scheme has been in continuous operation at Dinard in Brittany, France, since its commissioning in 1963. It is therefore of interest to review any fisheries impact studies that have been undertaken since that time in relation to La Rance. Environmental impact assessments were not routinely carried out in France during the 1960s and there appear to have been no studies carried out prior to or during construction. TLSB has obtained an independent translation of a French language doctoral thesis by Le Mao (1985) which studied the fisheries impacts of La Rance in the early 1980's, which is reviewed here.
- 9.5.3.102 The scheme at La Rance uses 24 bulb turbines, (horizontal axis; diameter 5.35 m; fixed speed 93.75 rpm). These are slightly smaller in diameter and faster running than those proposed for the Project (horizontal axis bulb turbines, 7 m diameter, < 70 rpm, fixed or variable speed), but close enough to provide a reasonable comparison. The smaller size and faster, fixed running speed of La Rance turbines would be expected to increase the risk of fish injury relative to the TLSB design.
- 9.5.3.103 Furthermore, rather than operating from a lagoon, La Rance basin is formed from a natural ria (drowned estuary) and encloses an area of 22.5 km² (cf. 10.5 km² for the Project), the barrage, with turbines, enclosing its seaward opening. As for the Project, water exchange between the basin and the sea is via either the turbines or adjacent sluices. This situation has persisted since 1963, prior to which during construction the ria was closed off from the sea, preventing natural exchange of either water or aquatic organisms. Le Mao's study provides a treatise on the marine ecology of La Rance basin, covering studies (unrelated to the tidal power scheme) from the early in the 20th century before construction of the scheme to his time of writing.
- 9.5.3.104 Early records prior to the 1960s make no mention of anadromous fish such as salmon or shad. This is of note since there has been some conjecture over whether closure by the barrage during the construction phase actually caused migratory populations to die out. This appears not to have been the case. The fish community at that time was represented by a wide range of marine and euryhaline (tolerant to varying salinity) species, as well as European oyster (and other shellfish and cephalopod species). The community described is transitional water/inshore coastal mix, broadly similar from the present-day fish community in Swansea Bay described in the TLSB Baseline Fisheries review (Appendix 9.1, Volume 3).
- 9.5.3.105 Moving to Le Mao's study period in the early 1980s, Le Mao describes a flourishing fish community of broadly similar structure. Examples of key fish species making up most of the biomass included:
- i. Bass
 - ii. Flatfishes: flounder, plaice etc.
 - iii. Mullet
 - iv. Herring, sprat and sardine
 - v. Gadoids (cod family)
 - vi. Elasmobranchs (skates, rays and dogfish)
 - vii. Sand smelt
 - viii. Sandeels



- ix. Stickleback *Gasterosteidae* spp.
- x. Gobies
- xi. Pelagic predators: garfish *Belone belone*, mackerel and horse mackerel.

- 9.5.3.106 Of the common diadromous species, salmon are not mentioned either prior to or after closure of the barrage; eels are recorded before and after; occurrences of sea trout are rare, and occasional Twaite shad have been recorded but not as a regular feature of the community. Smelt were recorded in the early 20th century and then only once again in 1977, after which they did not reappear to the end of Le Mao's reporting period.
- 9.5.3.107 Overall, therefore, Le Mao's study provides considerable confidence that a healthy, diverse and largely unchanged fish community can exist in harmony with a tidal barrage scheme. However, owing to the absence of any diadromous fisheries records pre-scheme, it throws little light on effects on these migratory species.
- 9.5.3.108 Le Mao's investigations into effects of turbine passage on fish were relatively informal and provide only qualitative information.
- 9.5.3.109 The overall picture given by Le Mao is of minimal evidence of injury as fish pass through the tidal turbines. His information comes mainly from two sources: visual observations made on a number of occasions when schools of fish could be seen passing the turbines; and examination of fish netted from the area of the sluice gates for signs of injuries. He reports that garfish of 100 cm length and squid of 100 cm length passed undamaged. He also noted that schools of herring passed through with no observable deaths, but that schools became scattered and more vulnerable to bird or bass predation. It should be noted that in Severn Tidal Power Group (STPG) experiments reported by Turnpenny (1988), high mortalities occurred only sometime after exposure to shear stress levels associated with turbine passage; these were caused by scale loss and consequent osmotic disruption. Such effects would not be apparent to when observing only the immediate event.
- 9.5.3.110 Le Mao puts the predation risk at La Rance into perspective: "[during observations on 14/9/83] a maximum of a thousand clupeids were caught [by seabirds] out of several tens of thousands" and "[during observations on 24/11/84] gulls only caught ten or so mullet in half an hour out of several hundred observed."
- 9.5.3.111 Cases of fish injuries were found in fish samples netted from around the barrage sluices. Here Le Mao found numerous instances of abrasion and crushing injuries in horse mackerel, mackerel and garfish that had become temporarily trapped in the area, but no evidence of turbine related injuries. He ascribed injuries mainly to contact with the barnacle-covered walls. In this context, Le Mao reports an interesting observation in bass taken from La Rance basin. Scale samples collected (twelve per fish) to allow age determination showed an unusually high incidence regeneration - a condition that occurs when scales have been lost, e.g. due to abrasion or hydraulic shear: 72 % of fish showed signs of regeneration in at least one of the twelve scales sampled from each fish, and all of the twelve scales had been regenerated in 12 % of bass collected. Bass is a physically resilient species and scale loss is survivable. Overall he comments that neither predation nor turbine passage injuries appeared significant in the context of the basin's populations as a whole.



- 9.5.3.112 Le Mao's study of fish at La Rance provides direct evidence that marine and euryhaline fish species can flourish in the context of tidal barrage power generation. As predicted for the Project, mortalities associated with turbine passage appeared to be minimal, although delayed mortality in delicate clupeid species could not be determined by the nature of his studies. Solomon (1988) reached a similar conclusion in his report to the Severn Tidal Power Group. Attraction of predators and increased predation of small fish was a clear feature but appeared only to affect a small proportion of passing fish.

Migratory fish studies on the Tawe Barrage

- 9.5.3.113 The Tawe Barrage was constructed in 1992, the first amenity barrage of its kind to be completed in the UK. The impoundment has resulted in a largely freshwater lake upstream of the barrage which runs for the majority of the original estuary (Russell et al., 1998). A pool and traverse fish pass was included in the impoundment to allow for the movement of migratory fish (Figure 9.30). The primary weir is set between MHWN (7.23 m A.C.D.) and MHWS (9.48 m A.C.D) at 8.05 A.C.D. A secondary weir is set at 8.35 m A.C.D. This arrangement allows an estimated 71 % of tides to overtop (for approximately 16 % of the time) (Mee, Kirkpatrick, & Stonehewer, 1996).
- 9.5.3.114 A study investigating salmonid behaviour migrating past the Tawe barrage was conducted by Mee et al. (1996). Over a period of two years 127 adult fish (both salmon and sea trout) were tagged. Fish were sourced both above the barrage (72) and below (55). A combination of acoustic and radio tags were used to monitor their movement following release below the barrage. Results indicated that 38 (29.9 %) of released fish migrated past the impoundment, 53 (41.7 %) were last recorded in the estuary downstream of the barrage, 2 (1.6 %) were not detected and a single fish (0.8 %) was captured in another river. Successful approaches were primarily made during periods close to high tide, with a mean entry of three minutes before high water. Of the successful passes, nine fish entered through the fish pass, taking between 0.4 and 24 hours to ascend the fish pass. Strong correlation was found between successful entries to the impoundment and tidal state, with 78 % of fish found to do so over the primary or secondary weir during inundating tides.
- 9.5.3.115 A separate study (Russell et al., 1998), concurrent with the work from Mee et al. (1996), assessed the movement of a proportion of the same adult fish using HiRes methods (6 in 1993 and 22 in 1994). The majority of fish (73 %) were found to hold station below the barrage (< 10 m) for relatively long periods of time, a significant proportion being attracted by the plume of the fish pass.
- 9.5.3.116 In addition to adult passage, the behaviour of smolts in proximity of the barrage was investigated during their spring seaward emigration. Fish used were trapped 2.6 km above the head of tide using fyke nets. Over the course of the study, 52 smolts were tagged (31 salmon and 21 sea trout) and released within 30 minutes of capture to resume their downstream migration. Downstream progress of smolts was monitored using a sonar buoy array, from freshwater, through the impoundment, and to the outer estuary. Movements of smolts were found to be primarily nocturnal. Through the tidal and impounded sections of the river, up to the barrage, smolts were found to migrate with speeds equivalent to an inert object (5.8 ± 1.25 hours), whilst significant delays were encountered upon reaching the barrage (mean $\pm$ S.E. = 54.8 ± 23.1 hours in 1994; and, 42.9 ± 22.5 hours in 1995). Smolts were found to be attracted by the filling of the lock, and ultimately passed the barrier via a number of possible routes, including: over the weirs, via the fishpass and through the lock.

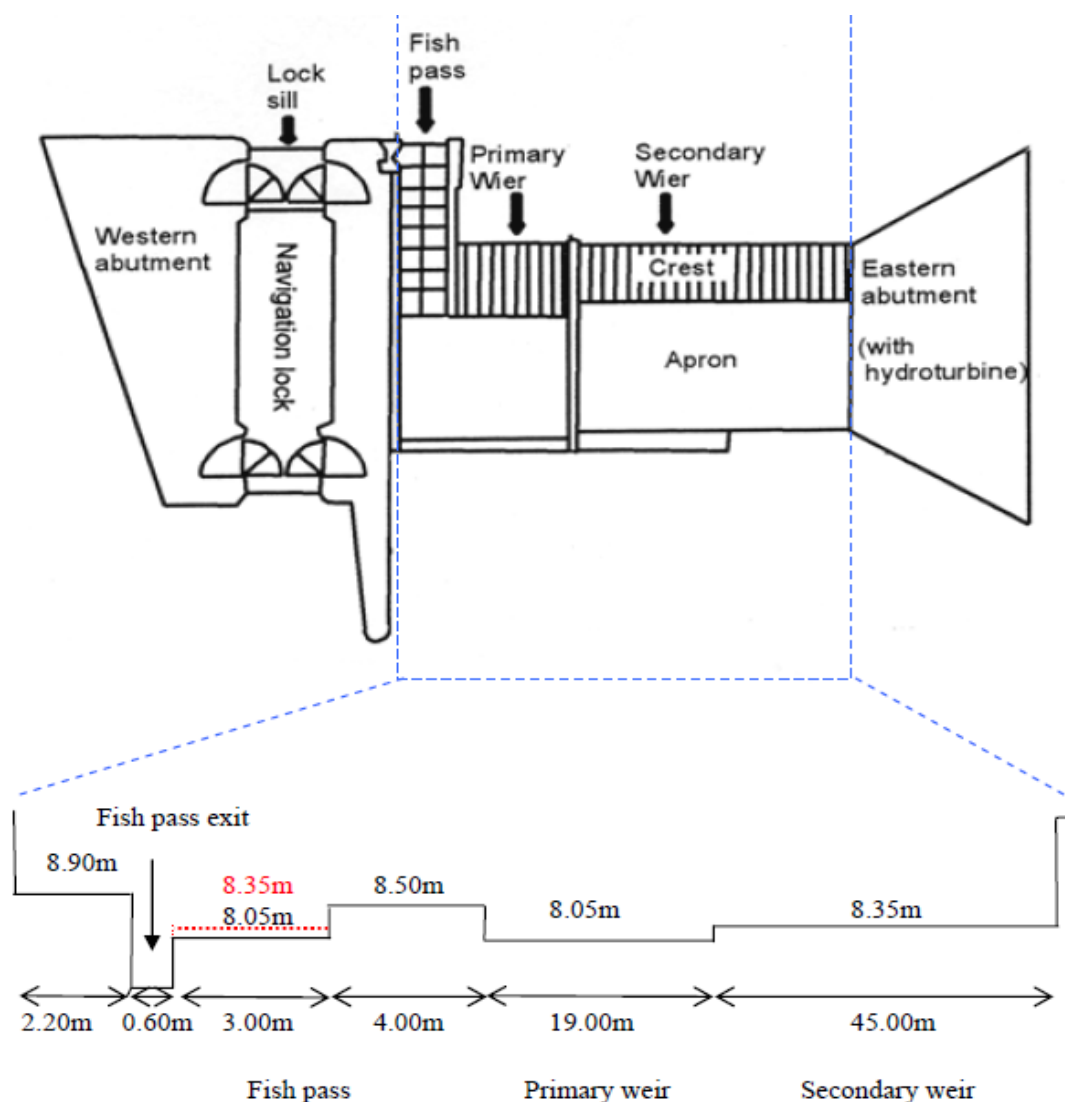


Figure 9.30 General arrangement of the River Tawe Barrage. Black levels are representative of levels before fish pass alteration, whilst red is level post alteration. (Reproduced from Washburn, 2005),

- 9.5.3.117 Conclusions drawn by the study indicated that several factors could be attributed to the delays experienced by the adult salmon, including: turbulent flows within the pass, poor fish pass design, time for physiological adjustments to freshwater, switch from passive to active migration. With regard to smolts, it was concluded that the barrage prevented smolts from using tidal currents to assist their movement through the estuary, representing a partial barrier to their migration. Russell et al. (1998) concluded by saying that both results from the Mee et al. (1996) study, and their own, showed that the barrage on the Tawe physically constrain the migration of salmonids, both adult and juvenile.
- 9.5.3.118 In light of the results from Mee et al. (1996) and Russell et al. (1998), in 2001, modifications to the fish pass were carried out in order to address the problems associated with excessive turbulence in the pools (i.e. low rates of energy dissipation). A doctoral thesis was carried out following the modifications to quantify the fish use of the modified fish pass (Washburn, 2005). The movement of migratory fish was studied through the Tawe Barrage fish pass using an underwater video system. Results indicated



that between July to October 2001 some 335 salmonid entered the impoundment through the fish pass, other species included mullet *Mugilidae* spp., bass and eel. An overall passage of 0.20 fish per hour of video was found. No data were provided for the number of fish which approached the fish pass versus numbers successfully ascending, rather, emphasis was placed on the relationship between successful passage and differing environmental conditions (i.e. tide, water quality and light), thus conclusions on efficiency can only be drawn in terms of the presence of fish within the fish pass under a range of conditions.

- 9.5.3.119 Contrary to earlier studies (Mee et al., 1996; Russell et al., 1998), Washburn (2005) indicated that the majority of salmonid fish entered the impoundment through the fish pass during periods of non-inundating tides, though both inundating and non-inundating tides led to successful passage. Diel movement patterns of fish indicated that there were differences in the timings of passage based upon tidal state. During July and August, 98 % of fish were found to exit the pass during daylight hours, whilst in September more fish were observed exiting the fish pass through the day. Washburn (2005) suggested that the improvements to the fish pass led to fish being able to use the pass at higher flow rates than was previously possible, with flows associated to peak passage falling between 6 and 8 m³ s⁻¹.
- 9.5.3.120 In summary, evidence suggests that following the construction of the River Tawe Barrage migratory fish incurred some delay during their movements between the tidal and non-tidal reaches of the estuary. Initially, this delay was exacerbated by the unsuitability of the fish pass constructed during the initial design of the project. However, following modification to improve energy dissipation levels within the pools in 2001, the fish pass now allows fish to migrate under a wider range of environmental conditions.
- 9.5.3.121 Water Framework Directive assessments concerning all waterbodies linked to the River Tawe, Neath and Afan have indicated that physical and morphological alteration represents the second biggest risk to achieving WFD objectives. Accordingly, it is likely that the carrying capacity, of the R. Tawe, if not all three catchments, is restricted by physical barriers, which is further supported by evidence provided in the River Tawe Salmon Action Plan (Environment Agency, n.d.). It is therefore recognised that river restoration or fish passage schemes would greatly benefit the catchments in the Swansea Bay area.

Waterborne noise and vibration from turbines

- 9.5.3.122 Noise source levels for operating turbines are not widely available, but a study by Miyamoto et al. (1989) on three North American sites provides indicative levels and decay rates (Figure 9.31b). The turbines studied by Miyamoto et al. (1989), listed below, are of comparable size to those proposed for the Project (7 m diameter):
- i. Bonneville 2, vertical Kaplan 7.62 m diameter;
 - ii. Lower Granite, Vertical Kaplan 7.92 m diameter; and
 - iii. McNary, vertical Kaplan 7.11 m diameter.
- 9.5.3.123 Maximum sound levels were found to occur at frequencies between 10 and 70Hz.
- 9.5.3.124 Miyamoto et al. (1989) cite a maximum sensitivity for Atlantic salmon at 160 Hz and a hearing threshold of -20 dB re 1 µPa. From Figure 9.31a), the sound level was approximately 30 dB above hearing threshold for salmon at the turbine housing

entrances identified above. Nedwell et al. (2007) report that fish begin to react at levels around 50 dB above the auditory threshold, indicating that salmon, whilst being able to hear the turbine noise at some distance away, are unlikely to be deterred by the turbine sound alone. Other more sensitive species such as herring or shad are more likely to be deterred in the vicinity of the turbines and as such will avoid the immediate area.

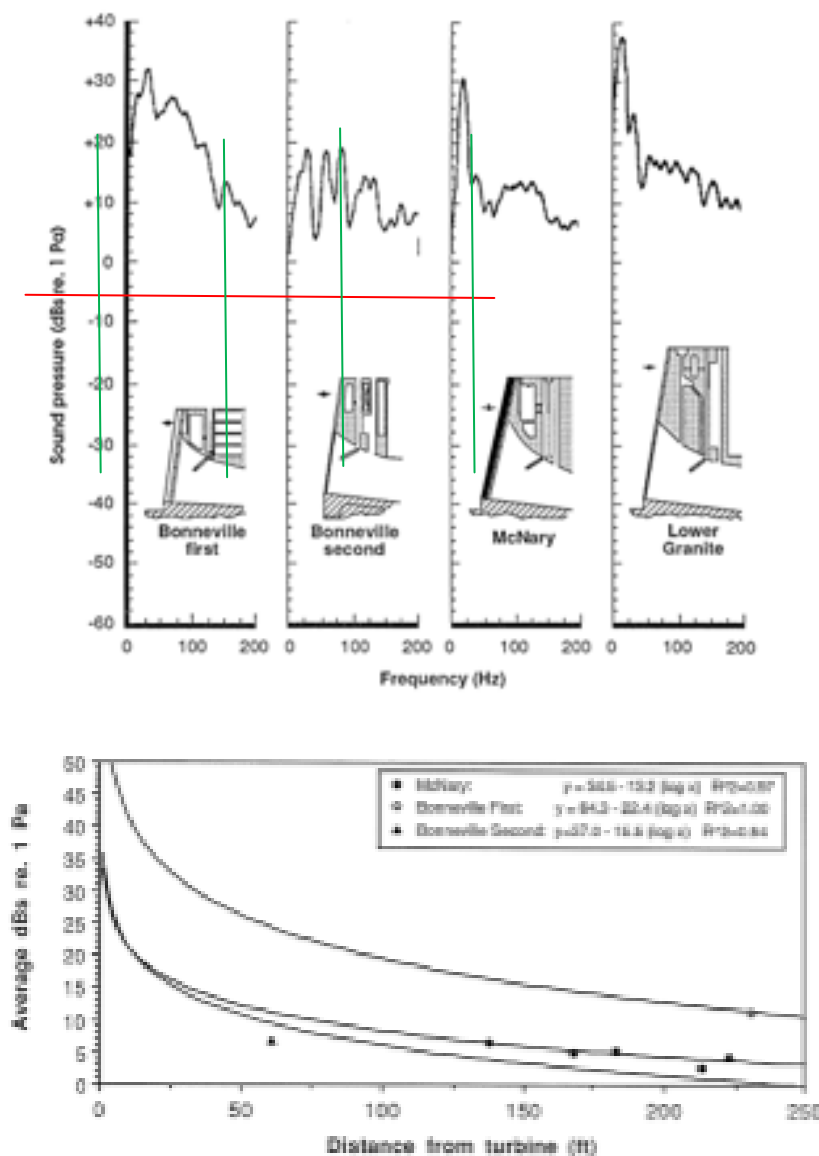


Figure 9.31 a) (above) Noise emission spectra at turbine entrances and b) (below) decay of sound pressure level with distance from operating turbines at three North American dams (Miyamoto et al., 1989). [Red horizontal line shows Atlantic salmon hearing threshold at 160Hz; green vertical lines show the 160Hz position.]

- 9.5.3.125 The sounds recorded in such studies are not confined to those generated by the turbines and will partly be due hydraulic noise associated with turbulent flow around other structures that form part of the relevant dam. These will vary from site to sites, as shown by the variations seen in Figure 9.31a).

Fluctuations in lagoon water level

- 9.5.3.126 Le Mao (1985), who investigated effects of operation of La Rance tidal power scheme (Brittany) on fish populations identified the effect of sudden level changes within the basin caused by turbine and sluice operations as the main impact of the scheme on fisheries, which was shown to cause mass mortalities of juvenile flatfish and other epibenthic species that became stranded. This occurred in 1983 as a result of a sudden change in the operating regime from ebb only to dual ebb/flood mode and fish kills were caused where normally subtidal habitat became tidally exposed.
- 9.5.3.127 Fish stranding has also been associated with 'hydro-peaking', the pulsed operation of run-of-river hydropower schemes to meet short-term increases in power demand on some rivers (Cushman, 1985).
- 9.5.3.128 The TLSB scheme will not operate in a hydro-peaking mode but is designed to consistently mimic the natural tidal cycle, although with a phase-shift. The rate of intertidal drying in Swansea Bay is naturally rapid owing to the shallow slope of the Bay and has been modelled as described in Chapter 6 Coastal Processes with results shown below in Figure 9.32. Overall, the average rate of exposure is slightly increased with the Lagoon operating (from 0.9 up to 1.1 ha/min), as is the maximum rate of exposure (from 2.96 up to 3.17 ha/min). Thus exposure rates will exceed the natural rate only on the more extreme spring tides.

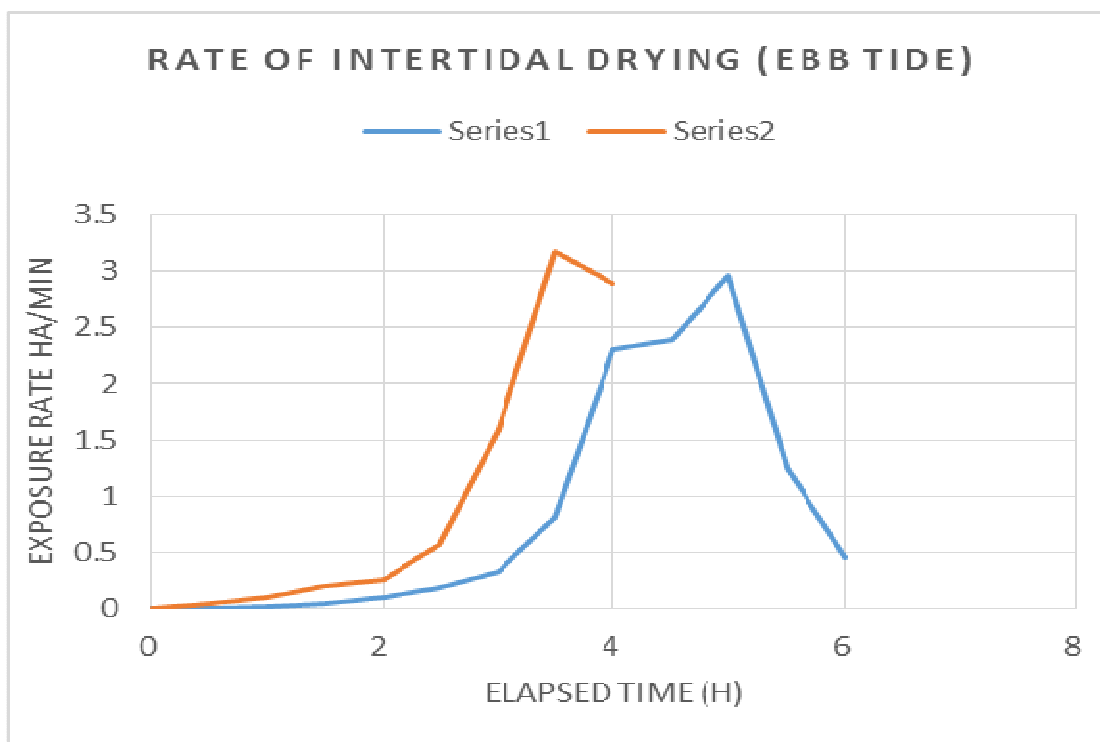


Figure 9.32 Intertidal exposure rate (in hectares per minute), based on half-hourly timesteps between the levels of MHWS and MLWS on the foreshore area that would be inside the Lagoon. Series 1: Baseline case; Series 2: with Lagoon.

- 9.5.3.129 Should there prove to be need to modify exposure rates, the TLSB scheme will have complete control over the Lagoon filling and emptying rates by opening individual gates or turbines to control the flow.



Fish passage via sluice gates

- 9.5.3.130 During periods when the sluice gates are opened to maximize filling and emptying of the Lagoon (towards high and low water conditions), fish will be able to enter or leave via the sluice gates. This is expected to be a low-risk route for fish passage owing to the large sluice openings and relatively low velocities (1.4 to 5.2 ms^{-1} over a differential hydraulic head range of 0.1 m to 1.4 m) compared with the turbine route ($10\text{-}11 \text{ ms}^{-1}$). Up to ten sluice gates will be installed within the turbine housing, each of approximately 15 m width and with a 9 m opening height.
- 9.5.3.131 Fish injuries caused by passage of sluices are commonly associated with contact and abrasion near to the edges of the sluice gates and associated walls and civil structures. Where water is forced at high velocities through narrow sluice openings, hydraulic shear-stress could also become an injury factor.
- 9.5.3.132 Turnpenny *et al.* (1992) estimated hydraulic shear stress values associated with local shear fields at a maximum fluid velocity of 5.4 ms^{-1} (*cf.* maximum velocity of 5.2 ms^{-1} through sluice gates) to be up to 206 Nm^{-2} . They also showed that salmonids (*Salmo salar*, *S. trutta*) and eel exposed to this shear-stress level exhibited no injuries or mortalities in the ensuing 7-d period. Clupeid fish (*Clupea harengus*, *Alosa fallax*) were more sensitive and suffered scale loss, eye haemorrhages at subsequently died when exposed at this level.
- 9.5.3.133 For species other than the more delicate pelagic fishes, including e.g. sprat (*Sprattus sprattus*), predicted maximum shear stress levels are not high enough to cause injury. For the more sensitive species, any high shear stress values will be limited to a critical border zone within 10 cm of the boundaries. For an opening of dimensions $15 \text{ m} \times 9 \text{ m}$, the open area is 135 m^2 . The periphery measures 48 m and therefore the critical border zone has an approximate cross-sectional area of $48 \times 0.1 = 4.8 \text{ m}^2$. This equates to 3.55% of the open area and therefore is the maximum injury rate per pass estimated for pelagic species.

Increases in artificial light emissions

- 9.5.3.134 Lighting will be incorporated in the design of the Project to ensure a safe environment for operatives and members of public accessing the facility. The building would be uplit and lighting of the immediate external area will be provided. Amenity lighting of the public realm would extend to the walkways of the western landfall and at a lower intensity towards the eastern landfall.
- 9.5.3.135 Light may act as a repellent or attractant to fish depending on species and/or life stage. Species such as eel are negatively phototactic at all life stages. Both the movement of glass eel and elver into freshwaters and of pubescent silver eel to sea typically occur at night (Brujls & Durif, 2009), and light falling onto their migratory pathway may have a marked obstructive effect on their movement (Sørensen, 1951) to and from the River Tawe. Flume studies have demonstrated that silver eel show a strong avoidance reaction to light, with 65% of eels deflected with a fluorescent lamp at an illumination level of $3\text{-}5 \text{ mLux}$ (Haddingh *et al.*, 1999).
- 9.5.3.136 Positive phototaxis is exhibited by herring larvae which are present throughout the Bay. The Juvenile herring may be attracted to light sources where they illuminate the water surface. Swansea Bay, with the city backdrop, will be subject to existing lighting which would be more than on a more remote section of coast, for instance, and as such this



forms part of the baseline. As discussed above, the offshore building will be uplit and the lighting of the walkways will generally be contained to the seawalls. As such, illumination of the surface waters and potential effects on herring is not anticipated to be significant. Overall the impacts of lighting are considered negligible on all species.

Potential deterioration in water quality

- 9.5.3.137 Through its physical presence the Project has the potential to disrupt water movement and influence the water quality in the Bay. Effects will be limited to transitional and coastal water bodies, as the effects of the Project will not propagate into freshwater water bodies owing to their spatial segregation and tidal influences.
- 9.5.3.138 Swansea Bay is designated as a Heavily Modified Water body under WFD classification (see Chapter 7: Water Quality Assessment) and as such must meet the water quality standards set in the Directive. As part of its WFD monitoring, NRW indicated that in 2012 Swansea Bay was judged as having **good** water chemical status, meaning that all priority substances (Benzene; Lead and its compounds; Mercury and its compounds and Nickel and its compounds) identified as posing a risk to the water body were recorded as **high** (indicating a low level). Additionally, all ecological supporting elements, with the exception of Dissolved Inorganic Nitrogen (Moderate), also met a **high** standard.
- 9.5.3.139 Physico-chemical parameters which serve to support healthy fish populations include the following: temperature; dissolved oxygen; salinity and nutrient levels. Extensive water quality modelling of these parameters, and the influence of the Project on them, has been undertaken and is presented in Chapter 7, Water Quality Assessment. Results from the modelling are discussed in the context of fish and shellfish below.
- 9.5.3.140 Summer temperatures within the Bay will remain largely unaffected by the presence of the Lagoon, whilst in winter, a maximum increase of 0.5 °C in the Bay, and up to a 1 °C increase within the Lagoon itself are predicted. No temperature hotspots are predicted. Overall, the modelled outputs indicate that changes will not significantly affect fish and shellfish populations within the Bay, and are not likely to outside the limits of their thermal preferenda (Wither et al., 2012).
- 9.5.3.141 Following the construction of the Project a net increase in salinity is predicted between Mumbles Head and the Lagoon wall (1 to 5 psu), whilst a decrease in salinity is expected east of the Lagoon wall, in proximity to the Neath estuary (1 to 5 psu). A more pronounced increase in salinity is projected to occur within the Lagoon itself, as the water within the Lagoon will be segregated from the freshwater discharges from the R. Tawe and Neath, modelling indicates an overall shift in range from 15-30 psu to 25 - 30 psu; this will be restricted to shallow waters. Spatial distributions of fish within estuarine and coastal waters are often correlated with salinity gradients. Fish found within Swansea Bay are already subjected to a naturally high variability in salinity, primarily resulting from freshwater flows and strong tidal movements. Fish surveys (see Appendix 9.2, Volume 3) have indicated that marine species, such as turbot, are found in numbers at intertidal survey locations in proximity to the estuaries of both the R. Tawe and Neath, thus salinity within the Bay is not currently inhibiting movements of stenohaline fish (species which do not like fluctuations in salinity). Overall, the changes within the wider Bay area are very unlikely to lead to spatial shifts in fish populations. Effects within the Lagoon itself will be more significant, euhaline conditions will become more prevalent, thus marine species may become more numerous within the Lagoon, however, overall diversity is likely to remain unchanged. Higher salinities expected within the Lagoon, and more concentrated freshwater plumes against the external seawalls,



should also prove beneficial to diadromous fish migrating inshore as they will be discouraged from entering the Lagoon, thus running less risk of injury through turbine encounter.

9.5.3.142 Dissolved available inorganic nitrogen (DAIN) levels are predicted to be reduced within Swansea Bay following the construction of the Lagoon; this will be offset by marginal increases in transitional water bodies. Overall, a small change in DAIN is likely to occur, which is not expected to significantly affect WFD class for the waterbodies in question. Phytoplankton distribution within the Bay is likely to remain largely unaffected.

9.5.3.143 Current levels of Dissolved Oxygen (DO) with Swansea Bay are close to saturation, and are well above a WFD **high** standard for coastal waters. Very small changes in DO are likely to occur as a result of the Lagoon, these will be most significant within the bounds of the Lagoon wall, but will not adversely affect water quality. In the context of fish and shellfish changes are not likely to have any effect, in terms of both dispersion, and density.

Creation of EMFs

9.5.3.144 It is proposed to transmit electricity from the turbines to the substation at Baglan Bay along three single core XLPE cables (800 mm²).

9.5.3.145 Electromagnetic fields (EMF) generated from the cable have been suggested to have the potential to disrupt electrosensitive and magnetosensitive fish; typically these include elasmobranchs, lamprey, eel and salmon (Gill et al., 2005).

9.5.3.146 The EMF is composed of both an electric (E) and an induced magnetic (B) field (Cada et al. 2011) that will radiate into the environment within the immediate vicinity. Electric fields are normally fully contained within the insulation surrounding the cable and are not sensed by fish, whilst B fields propagate outside the cable and can be sensed by electro-sensitive species. Where a fish or tidal movement occurs through a B field, a further induced electric (iE) field can be created (Gill & Bartlett, 2010). The main potential impact of any electric field would be to disrupt the sensory feeding cues of some benthic species, whilst magnetic fields may impact upon fish fauna by impairing the orientation and migratory behaviour of diadromous fish.

9.5.3.147 Elasmobranchs are recognised as being very sensitive to EMF stimuli. However, the location of the planned cable either in the western seawall of the Project or burial where it crosses the River Neath is too far upstream to be of concern for this subclass of fish.

9.5.3.148 Diadromous fish, such as eel, have also been shown to display avoidance to EMFs. Westerberg & Begout-Anras (2000) have shown eel display some avoidance to a subsea 130 kV AC cable. The overall delay as a result of the cable is estimated at an average of 30 minutes (owing to its effect on swimming speeds). It should be noted that these trials were conducted in fully saline conditions, where eel are likely to be using magnetic orientation and where EMFs propagate further. Within an estuary this would differ as eel are more dependent on chemical cues and EMFs propagate less due to lower conductivities.

9.5.3.149 Studies carried out on a 33 kV cable crossing the Clwyd estuary in North Wales have indicated elevated E fields ($> 70 \mu\text{V m}^{-1}$). In theory, fields at these levels should have a negative effect on the movements of lamprey (as they have been shown to sense levels $< 10 \mu\text{V m}^{-1}$). Notwithstanding this the Clwyd is well known for its population of river



lamprey and salmonids (Kelly & King, 2001). This would suggest that the effect of the cables on lamprey and salmonids is restricted.

- 9.5.3.150 In the context of the Project, all cables leading from the turbine housing will be trenched within the Lagoon's seawall above the high water level. Fish fauna will be protected from the effects of directly generated electric fields arising from the cable by insulation surrounding the cable and as a result no impacts are expected from this source of electric field. Induced electrical fields generated by the magnetic field will be reduced by locating the cable above high water level along the Lagoon wall. The magnetic field will diminish rapidly and with increasing distance from the cable and this source is unlikely to illicit a behavioural response in fish fauna.
- 9.5.3.151 Once onshore, the electric cables will run sub-surface to terminate at Baglan Bay substation. The cable route will cross the course of the Neath River. It is currently proposed that the cable will pass under the river bed (2.1 m depth), perpendicular to the channel through existing pipe work or through new infrastructure. Alternatively the cables would cross the River Neath by the installation of a single large diameter or 3 smaller diameter ducts by directional drill, approximately 650m in length. The duct(s) will be installed with approximately 10m clearance from the top of the duct to the river bed above.
- 9.5.3.152 Whilst burying a cable will not affect the magnitude of the magnetic field, the field will diminish with increasing distance from the cable in direct proportion to the current (amperes) passing along the cable.
- 9.5.3.153 Electromagnetic fields produced from the cables have been modelled (Table 9.24). Results indicate that electric fields (E) will be fully contained by the shielding around the cables, whilst magnetic (B) fields will be released into the local environment, but will be limited in strength.

Table 9.24 Modelled electromagnetic fields produced by cable.

Distance from cables (m)	Trefoil cleated (μT)	Trefoil in 180 mm OD ducts (μT)
1	8.300	13.600
5	0.333	0.544
10	0.083	0.136
50	3.326×10^{-3}	5.443×10^{-3}

- 9.5.3.154 The magnetic fields produced by the cables even at 1m distance (8.3 μT) are below levels which magnetosensitive fish such as elasmobranchs are known to detect and respond to (36 μT and in the range of 25-100 μT) (Gill et al., 2005). Electromagnetic fields generated from the electrical transmission cable are therefore not expected to impact on fish fauna within the Bay (interpreted as interference with prey detection and avoidance or attraction to EMF) or impede those returning to rivers.

Waterborne noise and vibration from recreational activities

- 9.5.3.155 Noise pollution, emanating from anthropogenic sources, has the potential to disturb fish. The provision of facilities within the Lagoon to accommodate water based recreational activities therefore has the potential to impact upon fish.
- 9.5.3.156 Activities which are likely to be the source of excessive noise include power boating and jet skiing. It is proposed that the Lagoon will be used for sailing, rowing and open water swimming.



- 9.5.3.157 Waterborne noise emissions will be contained by the Project's seawall and will not propagate outside the Lagoon. Fish outside the Lagoon will not be affected. It is likely however that some fish populations will become established, at least seasonally, within the bounds of the seawalls (e.g. mullet).
- 9.5.3.158 The waterborne noise produced by powered recreational craft is likely to be temporary and localised in nature. Marinas provide refuge and feeding environments for a range of fish guilds, and there is evidence that indicates fish populations become well established within both marina and port environments where noise emissions from powered craft are commonplace (Dicken, 2010). The potential impact to fish populations within the Lagoon as a result of recreational noise is considered to be negligible.

Increased pressure on fish populations as a result of recreational angling

- 9.5.3.159 Recreational angling within Swansea Bay primarily targets marine fish, with fishing from beaches, rocky outcrops and boats (private and commercial charters). Capture of diadromous species and Section 42 priority species of fish (S. 42 Natural Environment and Rural Communities Act, 2006) are however occasional (Thomas, B., Pers. comm. 2013).
- 9.5.3.160 Recreational angling can currently be undertaken along some 1.7 km of beach stretching from Crymlyn Burrows to the West of the mouth of the River Neath. The existing western breakwater to the entrance of the River Tawe is a popular fishing venue. The eastern breakwater arm is ABP land and as such has restricted access. Some clubs have permission from ABP to fish from their land.
- 9.5.3.161 During the operational phase of the Project, recreational anglers will be permitted to fish in the Lagoon, and from the Lagoon wall, continuing to target marine species. Platforms will be installed along the length of the Lagoon wall to facilitate safe access for this pursuit, allowing direct access to deep water at all states of the tide. Whilst it is likely that new facility will increase angling activity within the Bay, by a currently undetermined amount, the impact on the sustainability and viability of marine and diadromous stocks including section 42 priority species of fish stocks from increased angling activity as a result of the Project is considered to be insignificant.

Entrainment from draghead

- 9.5.3.162 Fine sediments are likely to accumulate in certain areas of the Lagoon during operation. In order to remove these maintenance dredging is proposed. As discussed within construction impacts demersal fish are most at risk from being entrained by dredging equipment.
- 9.5.3.163 The majority of fish will be discouraged from swimming in the immediate vicinity of dredging activity as a result of the noise levels associated with it. However, fish which inhabit substrate, such as sandeel, are likely to remain buried, and thus are more susceptible to entrainment.
- 9.5.3.164 It should be noted that the overall risk to sandeel from maintenance dredging is low as accretion is likely to be made up of fine sediments which are not preferred by sandeel. For other species losses are expected to be within natural variation.



9.5.4 Decommissioning effects

9.5.4.1 After the lifetime of the Project (assumed to be 120 years), the Project will either be upgraded or the turbines and sluice gates will be removed, and the tide allowed to flow through the resultant gap in the structure. For the scenario where the Project is upgraded, similar impacts are expected to the operational phase described above. The section below highlights possible impacts on fish were the turbines and sluice gates to be removed. The effect of each impact is quantified for each of the VERs identified in tables 9.28 to 9.38.

Increases in suspended sediment and sediment deposition

9.5.4.2 The removal of the turbines and sluice gates would be through use of the gantry cranes on the wall and as such any resultant increases in sediment would be minor, temporary and localised. The change to flows patterns (i.e. return to natural flows through the turbine and sluice gate structure) is unlikely to disturb or remobilise sediment within the Lagoon. The volume of sediment deposited and potentially remobilised however would be dependent on the continuation of the maintenance dredging regime adopted throughout the operational phase of the Project.

9.5.4.3 Overall the effect of removal of the turbines and sluice gates during the decommissioning phase would be temporary, and would mobilise significantly less suspended solids than during the construction phase resulting in an insignificant effect on fish fauna. If maintenance dredging was ceased there would be some siltation of the Lagoon and potential loss of some intertidal habitat possibly to saltmarsh. The overall effects on the fish and shellfish populations of the Bay are expected to be insignificant.

Increases in underwater noise and vibration

9.5.4.4 The primary activities leading to increased underwater noise and vibration during decommissioning would be linked to vessel movement. However, as the removal of the turbines and sluice gates would be through use of the gantry cranes on the wall, this is anticipated to be minimal. There may be temporary displacement of fish around particular decommissioning activities, but due to the nature of the works, overall noise from decommissioning is unlikely to have a significant effect on resident or migratory fish in the Bay.

Improved connectivity between habitats within and outside the Lagoon

9.5.4.5 Removal of the turbines and sluice gates would allow free-passage of fish into the Lagoon. This would re-connect the area of partially fragmented habitat which could again be used for spawning, nursery and foraging habitat for fish.

9.5.5 Cumulative effects

9.5.5.1 Certain projects and activities within the vicinity of the study area have the potential to contribute cumulatively to the impacts on fish and shellfish ecology from the Project. These include:

- i. Active dredging areas (e.g. Monkstone cruising and sailing club; R. Neath and Tawe navigation channels, Bristol Channel (On-going);
- ii. Coal gasification activity within Swansea Bay (conditional licence reissued);
- iii. Infrastructure redevelopment:



- iv. Mumbles pier (Completion expected end of 2013)
- v. RNLI lifeboat station (Completion expected 2014)
- vi. Port Talbot Harbour redevelopment (Status unknown)
- vii. Tawe Barrage (Operational);
- viii. Baglan Bay Power Station (Operational);
- ix. Mumbles Oyster Project (Licensed – status unknown);
- x. Mussel several orders (Licensed);
- xi. Tata Steelworks industrial water abstraction (Operational and planned expansion); and
- xii. Severn Barrage (in abeyance).

9.5.5.2 The effect of each impact is quantified for each of the VERs identified in tables 9.28 to 9.38.

Increase in suspended sediment and sediment deposition

- 9.5.5.3 In addition to the construction of the Project, other developments and activities have the potential cumulatively to increase the level of sediment suspension and deposition within the study area.
- 9.5.5.4 Activities/projects identified as having a cumulative potential impact are the active dredging areas, such as the Neath and Swansea (Tawe) Channel approaches and the potential coal gasification activity in Swansea Bay.
- 9.5.5.5 Little information is currently available regarding coal gasification within Swansea Bay.
- 9.5.5.6 Dredging and drilling will be the most likely processes to increase the levels of suspended solids and deposition.
- 9.5.5.7 Sediment plumes associated with the above, may lead to intermittent increases in sediment loadings, the effects of which will be most severe in proximity to their source and if they overlap with the construction work on the Project. However, the probability of plumes associated with the Project overlapping with ongoing maintenance dredging of the R. Neath and Swansea navigation channels is considered low.
- 9.5.5.8 No published evidence has been found to indicate the extent of the potential sediment releases from the coal gasification works. However, given the nature of coal gasification, it is projected that sediment releases will be temporary and localised. Typically, once boreholes have been drilled no further sediment releases occur, as gas is extracted through combustion.
- 9.5.5.9 Given the high background figures of suspended solids within the Bristol Channel and the potentially short, temporary period of any in combination activities that may result in elevated suspended solids the significance of this impact is considered to be insignificant.



Increase in subsea noise and vibration levels

- 9.5.5.10 During the construction, operation and decommissioning of the Project there are likely to be levels of subsea noise emission above natural ranges (see Chapter 19: Noise and Vibration). Additional projects which may contribute to noise emissions that could have a cumulative impact include: infrastructure redevelopments, active dredging areas and coal gasification work.
- 9.5.5.11 Dredging, drilling and piling will be the most likely processes to increase the levels of subsea noise emissions.
- 9.5.5.12 Increased vessel movements could also contribute to higher underwater noise levels. However, both Port Talbot and Swansea Ports have significant commercial vessel traffic, which results in high levels of background subsea noise. Recent survey work has indicated ambient noise levels to be in the region of 120 dB (See Chapter 19: Noise and Vibration). It is likely, therefore, that noise emissions from increased vessel activity would not be significant.
- 9.5.5.13 There is little potential for cumulative noise effects on fish and shellfish populations in the study area as a result of combined effects from the above projects.

Habitat modification

- 9.5.5.14 The cumulative effect of dredging in the Neath and Swansea shipping channels during the construction of the Project has the potential to lead to compound habitat loss.
- 9.5.5.15 Dredging is likely to have both direct and indirect impacts on fish and shellfish, primarily through loss of foraging, spawning and nursery habitat. Additionally, coal gasification activities may have some impact on benthic habitats, though little information is currently available as to what such operations may involve.
- 9.5.5.16 Dredging activity in Swansea Bay has been ongoing for many years, is relatively intermittent, and restricted to specific areas. The time periods between the occurrences of this activity typically allow some re-colonisation to occur. Evidence indicates that a full re-establishment assemblage of the macrobenthic community in a dredged channel can occur in as little as six months (Guerra-Garcia et al., 2003). However, further evidence indicates that in some areas this process takes up to four years depending on a number of factors including substrate type and exposure (Boyd et al., 2003).
- 9.5.5.17 Prior to the closure of the BP chemical plant at Banglan in 2003, it was necessary for approximately 250,000 to 400,000 wet tonnes of sand to be dredged annually between their jetty and the Port of Neath's outer buoys. However, the current dredging involves smaller volumes, 70,000 to 100,000 wet tonnes per annum
- 9.5.5.18 No other projects listed above are predicted to lead to significant long-term habitat loss when considered with the Project.
- 9.5.5.19 Temporary losses in habitat heterogeneity will result from the removal of structures such as piles (e.g. redevelopment of Mumbles Pier), which have an established sessile fauna. Colonisation of new piers is likely to be rapid although dependent on the time of year the new piles are installed. Replacement of piles is programmed to be completed well in advance of the proposed tidal Lagoon development. No cumulative impact is anticipated.



- 9.5.5.20 Interactions between the activities identified above are not likely to further increase the impact of the work occurring for the Project, primarily due to their spatial isolation.

Habitat fragmentation and isolation

- 9.5.5.21 As discussed previously the Tawe Barrage is known to add delays to the migration of diadromous fish within the R. Tawe estuary. Russell et al. (1998) indicate that salmon typically move past the structure when the barrage is overtopped, this only occurs during tides > 8.05 m which account for approximately 71 % of tides, additionally inundation only lasts for 16 % of the tidal cycle.
- 9.5.5.22 The IBM indicates that maximum delay attributable to the Project will be at most two tidal cycles at any state of the tide (this is for less than 1 % of fish).
- 9.5.5.23 In light of the above, delays associated with the proposed Lagoon are deemed minimal in comparison. As a result the overall cumulative delay will not be significant.

Entrainment by turbines and water abstractions

- 9.5.5.24 Baglan Bay Power Station is an indirectly cooled facility which abstracts water from the Tennant Canal; typically fish mortalities associated with entrainment at this type of site are minimal (Langford, 1983). The watercourse from which water is abstracted is located between Aberdulais and Port Tennant. Owing to the lentic conditions of the canal diadromous fish, with the exception of eel, are very unlikely to enter the watercourse. The abstraction is screened via a coarse screen with 1 inch bar spacings, and a secondary rotating screen with 4 mm mesh. The power station is currently in the process of upgrading its screening facilities to comply with The Eel (England and Wales) Regulations 2009, and must complete this by 2015. Owing to the restrictive nature of the above statutory instrument it is projected that no diadromous fish will be abstracted at this intake following the upgrade. Current entrainment rates of eel are thought to be negligible (Donnelly, M., pers. comm. 2013).
- 9.5.5.25 Given the above, cumulative impacts in respect of entrainment through abstraction are considered insignificant.

9.5.6 Mitigation measures

- 9.5.6.1 Table 9.27 at the end of this section gives a summary of proposed mitigation measures to offset the potential impacts on fish and shellfish. These are discussed further below. For a description of all mitigation please refer to Chapter 23 (Mitigation and Monitoring).

Construction waterborne noise from Impact piling for the temporary cofferdam

- 9.5.6.2 Low noise piling methods (vibro-piling) will be used where possible for the majority of the piling operations to minimise impacts on marine mammals and fish. The feasibility of low noise methods depends on the nature of the substrate into which piles are being driven and it is possible, that impact piling will be required on occasion to construct the temporary cofferdam around the turbine housing due to certain ground conditions (i.e. in areas of hard substratum). However, current evidence from ground surveys, seems to indicate that all piling will be possible using vibratory techniques.
- 9.5.6.3 If impact piling is required, 'soft-start' piling procedures will be adopted to initially repel fish within the vicinity of the construction work. This technique involving the "gradual ramping" of piling power is currently accepted by the Joint Nature Conservation



Committee (JNCC) as a best practice to reduce the risk of injury to mammals during marine piling operations (JNCC, 2010) and is also beneficial for fish: many fish species are able to discriminate sound source location (Fay, 2011).

Adaptation of lagoon seawall for spawning and habitat heterogeneity

- 9.5.6.4 To minimise the potential effect on Lithophilic spawning (e.g. herring) construction of western landfall and offshore cofferdam dredging in year 1 will not commence until end of March/beginning of April. In this way the herring will be able to spawn in February/March and juveniles move offshore before works start on site. Appropriate spawning media will then be placed at the foot of the western Lagoon wall by the end of August in year 1 so that it will be available for herring to use for September spawning run.
- 9.5.6.5 At other suitable locations around the Lagoon wall, appropriate spawning media will be placed to give herring spawning habitats with different degree of exposure. This surface of this media is also likely to be quickly colonised by marine macrophytes and other sessile organisms, and could promote the settlement of commercially important mollusc larvae (e.g. oyster).
- 9.5.6.6 Structures made up of hard surfaces could be designed to maximise the benefit to fish and shellfish (e.g. designed to have a rough texture). The use of concepts similar to BioReefs or BioBlocks will also be investigated to enhance the ecology of the area.
- 9.5.6.7 There is evidence to suggest that marine renewable energy installations (MREI) can provide a net benefit to biodiversity from such features (Inger et al., 2009).

Insertion of cables within the lagoon seawall and under the River Neath

- 9.5.6.8 As part of the Project design, to minimise the impact of EMFs on electrosensitive and magnetosensitive fish species, electric cables from the turbines will be buried within the Lagoon seawall, above the water level and appropriately insulated. The cable across the River Neath will be laid at a depth either within existing infrastructure or in a new duct at 10m.

Removal and relocation of fish and shellfish from the drained temporary cofferdam bund

- 9.5.6.9 Chapter 8: Intertidal and subtidal benthic ecology has identified that it is unlikely that there are any oysters beds present within the footprint of the Project, although communication with local fishermen indicate some maybe present within the wider Bay. However, prior to construction, oyster dredge trawls of the Lagoon footprint and areas to be disturbed during construction works will be undertaken. Any oysters identified will be translocated to the Centre for Sustainable Aquatic Research (CSAR) at Swansea University whilst construction works are ongoing, where their spawning behaviour and spat development will be monitored. In conjunction with SEACAMS/CSAR TLSB are also proposing an oyster enhancement programme as part of the operation of the Lagoon to try and restore native oyster beds in Swansea Bay, with the aim of promoting biodiversity and ecosystem health. Current oyster stocks are low and the remaining population in Swansea Bay consist of relatively old individuals. Once the Lagoon is in operation it is proposed that the spatfall of Swansea Bay oysters is maximised. Larvae and spat will be hatched in spatting ponds inside the Lagoon. Juvenile oysters which settle on cultch material will then be transferred to areas inside the Lagoon to grow. The Lagoon offers shelter from wave energy which could optimise growth and survival. Young



oysters could also be placed outside the Lagoon and performance in terms of survival, growth and impact on biodiversity could be monitored. Associated with the core aims, the programme offers opportunities for other research on the biology and ecology of oysters and the ecosystem services of bivalve reefs (Appendix 23.1, Volume 3).

- 9.5.6.10 As identified previously, it is expected that mobile fish species will move away from the construction area. However, some fish species (e.g. juvenile flatfish) may become trapped within the cofferdam as their avoidance of sound is very low; in such an eventuality a fish rescue may be appropriate before the total dewatering of the bund. Dewatering of the temporary cofferdam bund area will then be carried out using fish-friendly pumps.
- 9.5.6.11 As identified below, prior to the construction works it would be proposed to trawl for oyster/shellfish. With this mitigation it is anticipated that there should be no stranded shellfish within the temporary cofferdam bund.

Removal and relocation of shellfish from the dredged areas/seawall footprint

- 9.5.6.12 Prior to commencement of works it is proposed to trawl the proposed seabed area affected by dredging and construction of the seawall to collect any native oyster or shellfish that may be present. As discussed above, the native oysters will then be translocated to a temporary facility/safe area for the duration of the construction works. The oysters would be placed in spatting ponds in the Lagoon once works are complete and used as breeding stock for future initiatives to re-introduce the native oyster to the Bay.
- 9.5.6.13 It is anticipated that non-native marine species such as the slipper limpet *Calyptraeidae* spp. may also be present. Further information on non-native marine species present in the Swansea Bay area, along with issues to be investigated, have been presented in Chapter 8, Intertidal and Subtidal Ecology.

Behavioural fish guidance

- 9.5.6.14 Acoustic fish deterrents (AFDs) exploit the sensitivity of fish to sound. Hearing in fish varies according to species, typically falling within one of three broad categories: a) non-specialists, b) hearing generalists; and c) hearing specialists (see paragraph 9.5.2.36). Hearing generalists and specialists are most sensitive to sound, whilst non-specialists have a very low sensitivity. Typically signals produced by AFD devices are in the 20 to 500 Hz spectra, although in some cases frequencies outside this range have been used successfully (O'Keeffe & Turnpenny, 2005; Environment Agency, 2010a). Where peak hearing sensitivities of individual species are known from audiogram studies, signals can be adjusted seasonally for species targeted.
- 9.5.6.15 Maes et al. (2004) conducted trials at Doel nuclear power station to assess the effectiveness of AFDs in deflecting estuarine fish. The system was mounted in proximity to the cooling water intake of the power plant, and monitoring involved comparisons of fish impingement rates on cooling water screens between on and off periods. A summary of results from the study is provided in Table 9.25.
- 9.5.6.16 Results indicate that sounds with frequencies between 20 and 600 Hz can effectively repel fish from the intakes of power stations. Efficiency is species-specific, with hearing specialists, such as herring, being much more susceptible to AFDs than generalists such as goby. For salmonid fish (salmon and sea trout, deflection efficiencies of around 70 %

appear to be typical (O’Keeffe & Turnpenny, 2005). Neither lamprey nor eel, owing to their poor hearing capabilities, are significantly affected by AFDs.

- 9.5.6.17 An important factor to consider when planning the installation of AFDs are the velocities in proximity to the turbine intakes, and the range at which avoidance behaviour is expected. For maximum effectiveness the avoidance range should extend beyond the range at which current velocities exceed the swimming capacity of the target species. If velocities are above these, fish may become entrained regardless of the operation of AFDs. This is particularly important in a tidal context, where currents are naturally strong, and fish may not necessarily perceive an abstraction until they are very close to it.

Table 9.25 Modified from Maes et al. (2004). Percentage reduction in fish impingement at Doel nuclear power plant. The total catch (sum) and the daily mean $\pm$ S.E. sample size and (n=15) are given for test periods (AFD on) and for control periods (AFD off). Statistical significance was tested using *t*-tests.

Species	%	AFD on – Mean $\pm$ S. E.	AFD off - Mean $\pm$ S. E.
Significant reductions (i.e. < 0.05)			
<i>Clupea harengus</i> (herring)	94.7	139.7 $\pm$ 49.2	2659.5 $\pm$ 748.7
<i>Sprattus sprattus</i> (sprat)	87.9	286.5 $\pm$ 83.1	2376.5 $\pm$ 672.6
<i>Dicentrarchus labrax</i> (bass)	75.6	29.8 $\pm$ 7.4	122.1 $\pm$ 26.4
<i>Solea solea</i> (sole)	46.6	5.7 $\pm$ 4.7	10.7 $\pm$ 7.6
<i>Pomatoschistus</i> spp. (goby)	46.1	6110.1 $\pm$ 2715.4	11329.2 $\pm$ 4694.1
<i>Platichthys flesus</i> (flounder)	37.7	8.6 $\pm$ 6.0	13.8 $\pm$ 9.3
Insignificant reductions (i.e. > 0.05)			
<i>Liza ramada</i> (mullet)	75.8	7.3 $\pm$ 2.2	30.0 $\pm$ 17.1
<i>Syngnathus rostellatus</i> (pipefish)	43.3	26.3 $\pm$ 17.4	46.3 $\pm$ 45.6
<i>Anguilla anguilla</i> (eel)	37.3	9.4 $\pm$ 3.0	15.0 $\pm$ 5.1
<i>Lampetra fluviatilis</i> (river lamprey)	5.9	2.1 $\pm$ 1.4	2.3 $\pm$ 1.2
<i>Limanda limanda</i> (dab)	0.0	7.4 $\pm$ 7.4	7.4 $\pm$ 6.5

SE: standard error

- 9.5.6.18 Fish that are resident within the vicinity of the turbines for long periods may become habituated to acoustic signals if subjected to them repeatedly. For this reason, AFD operation should ensure that signals can altered at intervals to prevent habituation (Turnpenny & O’Keeffe, 2005). This can be achieved through the use of signal generators with multi-signal capability.
- 9.5.6.19 Installation of AFD systems should be preceded by acoustic modelling of installation to ensure that the spread of noise is not excessive, which might interfere with the natural movements of fish or marine mammals. Sound projector source levels are typically 160 dB re 1 μ Pa@1m, with frequencies covering a maximum range of 20-3000 Hertz. Normally effective ranges are limited to a few tens of metres. The actual acoustic field should be measured during the commissioning phase to allow adjustment of sound levels to the desired values.
- 9.5.6.20 In summary, deflection efficiencies for hearing specialists are expected to be high, typically between 80 to 90 %. Whilst for hearing generalists, such as many demersal species including cod and bass, deflection efficiencies are lower, in the 50 to 70 % range. Epibenthic fish are the least affected by AFDs, and deflection efficiencies are 15 % or less. Table 9.26 gives a summary of mortality expected from the turbines after AFD systems have been installed. This technology is now widely employed for excluding fish from coastal and estuarine power station cooling water systems and other types of water intakes.

Table 9.26 Fish mortality accounting for the use of AFD

Species	Mean mortality (%)	Expected AFD efficiency (%)	Residual mortality with AFD (%)
Atlantic salmon adult	0.87	70	0.26
Atlantic salmon smolt	0.12	70	0.04
Sea trout adult	3.40	70	1.02
Sea trout smolt	0.16	70	0.05
Shad	0.77	80	0.15
Herring adult	26.69	80	5.34
Eel adult	0.19	0	0.19
Eel elver	0.07	0	0.07
River lamprey adult	1.35	0	1.35
River lamprey transformer	0.02	0	0.02
Sea lamprey adult	1.86	0	1.86
Sea lamprey transformer	0.15	0	0.15
Bass adult	0.27	75	0.07
Bass juvenile	0.27	75	0.07
Plaice juvenile	0.69	0	0.69
Sandeel	0.01	50	0.01

Potential mariculture opportunities

- 9.5.6.21 As part of the Project, it is proposed to provide mariculture opportunities both within and outside the bounds of the scheme. Consideration has been given to schemes such as: encouragement of the re-introduction of an oyster fishery to Swansea Bay and creation of a lobster hatchery, with potential future opportunities for adapting hatchery to look at some key fish species (see Chapter 8: Intertidal and Subtidal Ecology).

9.5.7 Summary of impacts on fish and shellfish

- 9.5.7.1 Species of particular conservation concern have been assessed individually in Tables 9.28 to 9.36, whilst a group assessment has been undertaken for all other regional and local VERs of fish and commercial shellfish and is given in Table 9.37 and Table 9.38 respectively. Table 9.27 summarises the recommended mitigation for fish and commercial shellfish, which has been applied in Tables 9.28 to 9.38.

Table 9.27 Summary of recommended mitigation/enhancement to off-set impacts on fish and commercial shellfish

Potential Impact	Mitigation	Mitigation Code
Suspended sediment and deposition.	a) Use of appropriate geotextile lining to minimise the release of fine sediment into the water column. b) Selection of dredging equipment by the contractor will be appropriate to the depths and material types to be dredged and to minimise the creation of plumes. c) Marine habitat or seafloor disturbance clearing for the construction of the Project will be limited to the red line footprint of the development. Operations outside the scheme footprint will be prohibited. Boundaries will be enforced and distribution of worker awareness information. d) The Project will adhere to Best Practice Guidance identified in Marine Minerals Guidance 1: Extraction by dredging from the English seabed (Office of the Deputy Prime Minister, 2002), or other industry standards with respect to dredging and disposal of dredged material. e) Disposal of the dredge spoil not pumped into the Geotubes® will be undertaken at Swansea Bay licensed outer disposal grounds thereby presenting minimal risk of impact to sites outside the development	A

Potential Impact	Mitigation	Mitigation Code
	area. f) Dredging will be generally be undertaken between April and October. g) Preventing on-board screening or minimising material passing through spillways when outside the dredging area to reduce the spread of the sediment plume.	
Increases in underwater noise and vibration.	a) Low-noise piling techniques (e.g. vibropiling) would be the preferred method of cofferdam construction to reduce impacts on wildlife b) Soft start' piling procedures will be adopted for impact piling to minimise impacts when this technique is used.	B
Habitat modification.	a) Design of seawall will be adapted to increase heterogeneity and potential for fish spawning: I. Avoid smooth rock material/increase roughness; and II. Introduce gravel/appropriate media at the base of the seawall for fish which use substrate to spawn (e.g. herring). b) Removal and Relocation of Shellfish from the Dredged Areas/Seawall Footprint by trawling translocation of sessile species. c) Inclusion of a lobster hatchery within the design of the Lagoon. d) Mariculture facilities would indirectly provide suitable forage and refuge habitat to juvenile fish and shellfish. e) The use of concepts similar to BioReefs or BioBlocks will also be investigated to enhance the ecology of the area.	C
Habitat loss due to dewatering of cofferdam.	a) Use of fish friendly pumps when dewatering temporary cofferdam. b) Suitable screening (e.g. rose) of pump inlets. c) Fish and shellfish would be removed from the temporary cofferdam.	D
Habitat fragmentation and isolation.	a) Acoustic fish deterrents (AFDs) should be installed to discourage the ingress of fish to the Lagoon – The operation of these should be such that during periods of sluicing, free passage of fish is not deterred between the habitat outside and inside the Lagoon.	E
Entrainment and injury from turbines.	a) Inclusion of AFDs into Project design.	F
Creation of EMFs.	a) As part of the Project design, cables will be buried within the top of the Lagoon wall to avoid stray EMFs in areas frequented by fish. b) Cables are kept above the water line where feasible. c) Cables crossing beneath Neath Estuary will be placed at a depth of 10m, where possible.	G
Waterborne noise and vibration from recreational activities.	a) Recreational activities within the Lagoon will be encouraged in designated areas, with quieter areas identified in other parts of the Lagoon (see Chapter 4 Project Description).	H
Increases in light emissions.	a) Illumination of the site would be directional. b) The illumination of the water surface, especially outside the Lagoon, would be avoided where possible. c) The use of white mercury vapour lamps should be avoided.	I
Entrainment from draghead.	a) Dredging will be undertaken, where possible, between April and October.	J

Table 9.28 Summary of potential environmental effects on European eel *Anguilla anguilla*

Valued Ecological Receptor	Impact	Characterisation of impact	Direct/ Indirect	Frequency	Magnitude	Significance without mitigation	Confidence	Mitigation code (see Table 9.27)	Residual Significance and Confidence Level (adverse unless stated otherwise)
European Eel <i>Anguilla anguilla</i>	Construction phase								
	Increases in suspended sediment and deposition.	i. Behavioural disturbance.	Direct	Long term/ intermittent	Negligible	Minor	Probable	A	Insignificant; Probable
		ii. Injury and mortality.							
	Increases in underwater noise and vibration.	i. Behavioural disturbance.	Direct	Long term/ intermittent	Negligible	Minor	High	B	Insignificant; High
		ii. Injury and mortality.							
	Increases in artificial light emissions.	i. Behavioural disturbance.	Direct	Long term/ intermittent	Negligible	Minor	Probable	I	Insignificant; Probable
		ii. Loss/disturbance to foraging habitat.							
	Habitat modification.	i. Loss/disturbance to foraging habitat.	Direct	Long term/ continuous	Negligible	Minor	Probable	C	Insignificant; Probable
		ii. Gain of foraging habitat.							
	Habitat loss due to dewatering of cofferdam.	i. Injury and mortality due to dewatering.	Direct	Long term/ intermittent	Positive - Low	Moderate	Uncertain	n/a	Moderate Positive; Uncertain
		ii. Injury and mortality due to dewatering.							
	Entrainment from draghead	i. Injury and mortality	Direct	Long term/ intermittent	Negligible	Insignificant	Uncertain	n/a	Insignificant; Uncertain
		ii. Reduced fitness							
	Operational phase								
	Increases in suspended sediment and deposition.	i. Behavioural disturbance.	Direct	Long term/ intermittent	Negligible	Minor	Probable	A	Insignificant; Probable
		ii. Injury and mortality.							
	Habitat fragmentation and isolation.	i. Delays to migration.	Direct	Long term/ continuous	Negligible	Minor	Probable	E	Minor; Probable
		ii. Increased energetic costs.							
		iii. Fragmentation of migratory routes.							
	Habitat modification.	i. Loss/disturbance to foraging habitat.	Direct	Long term/ continuous	Negligible	Minor	Probable	C	Insignificant; Probable
		ii. Gain of foraging habitat.							
	Increased predation.	i. Injury and mortality	Direct	Long term/ intermittent	Positive - Medium	Major	Probable	n/a	Major Positive; Probable
		ii. Decreased fitness.							
	Entrainment from draghead	i. Injury and mortality	Direct	Long term/ intermittent	Low	Minor (juvenile)	Uncertain	n/a	Minor (juvenile); Uncertain
		ii. Reduced fitness.							
		i. Injury and mortality	Direct	Long term/ intermittent	Low	Minor (adult)	Uncertain	n/a	Minor (adult); Uncertain
		ii. Reduced fitness.							



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Valued Ecological Receptor	Impact	Characterisation of impact	Direct/ Indirect	Frequency	Magnitude	Significance without mitigation	Confidence	Mitigation code (see Table 9.27)	Residual Significance and Confidence Level (adverse unless stated otherwise)
	Entrainment and injury from turbines.	i. Injury and mortality.	Direct	Long term/ intermittent	Negligible	Minor (juvenile)	High	F	Minor; High (juvenile)
	Waterborne noise and vibration from turbines.	ii. Decreased fitness.	Direct	Long term/ intermittent	Negligible	Minor (adult)	High	F	Minor; High (adult)
		i. Behavioural disturbance.	Direct	Long term/ intermittent	Negligible	Insignificant	High	n/a	Insignificant; High
	Fluctuations in Lagoon water levels.	i. Behavioural disturbance.	Direct	Long term/ intermittent	Negligible	Insignificant	High	n/a	Insignificant; High
		ii. Injury and mortality.	Direct	Long term/ intermittent	Low	Minor	Probable	n/a	Minor; Probable
	Entrainment and injury from sluices.	i. Injury and mortality.	Direct	Long term/ intermittent	Negligible	Minor	Probable	I	Insignificant; Probable
	Increases in light emissions.	ii. Reduced fitness.	Direct	Long term/ continuous	Negligible	Minor	Probable	n/a	No impact; High
	Deterioration in water quality.	i. Behavioural disturbance.	Direct	Long term/ intermittent	Neutral	No impact	High	n/a	No impact; High
		ii. Increased mortality.	Direct	Long term/ intermittent	Neutral	No impact	High	n/a	No impact; High
	Creation of EMFs.	i. Behavioural avoidance.	Direct	Long term/ intermittent	Negligible	Insignificant	High	n/a	Insignificant; High
	Waterborne noise and vibration from recreational activities.	i. Behavioural disturbance.	Direct	Long term/ intermittent	Negligible	Insignificant	Uncertain	n/a	Insignificant; Uncertain
	Increased pressure on fish populations as a result of recreational angling.	i. Increased mortality.	Direct	Long term/ intermittent	Negligible	Insignificant	Uncertain	n/a	Insignificant; Uncertain
	Decommissioning phase								
	Increases in suspended sediment and deposition.	i. Behavioural disturbance.	Direct	Short term/ continuous	Negligible	Minor	Probable	A	Insignificant; Probable
		ii. Injury and mortality.	Direct	Short term/ continuous	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
	Increases in underwater noise and vibration.	i. Behavioural disturbance.	Direct	Short term/ intermittent	Negligible	Insignificant	Probable	n/a	Moderate Positive; Probable
	Improved connectivity between the habitat within and outside of the Lagoon.	ii. Injury and mortality.	Direct	Long term/ continuous	Positive - Low	Moderate	Probable	n/a	Moderate Positive; Probable



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Valued Ecological Receptor	Impact	Characterisation of impact	Direct/ Indirect	Frequency	Magnitude	Significance without mitigation	Confidence	Mitigation code (see Table 9.27)	Residual Significance and Confidence Level (adverse unless stated otherwise)
	Cumulative								
	Increases in suspended sediment and deposition.	i. Behavioural disturbance. ii. Injury and mortality.	Direct	Long term/ intermittent	Negligible	Minor	Probable	A	Insignificant; Probable
	Increases in underwater noise and vibration.	i. Behavioural disturbance. ii. Injury and mortality.	Direct	Long term/ intermittent	Negligible	Minor	Probable	B	Minor; Probable
	Habitat modification.	i. Loss/disturbance to foraging habitat. i. Gain of foraging habitat.	Direct	Long term/ intermittent	Negligible	Minor	Probable	C	Insignificant; Probable
			Direct	Short term/ intermittent	Positive - Negligible	Minor	Probable	n/a	Minor; Probable
	Habitat fragmentation and isolation.	i. Delays to migration. ii. Increased energetic costs. iii. Fragmentation of migratory routes.	Direct	Long term/ continuous	Negligible	Minor	Probable	E	Insignificant; Probable
	Increased predation.	i. Injury and mortality. ii. Reduced fitness.	Direct	Long term/ intermittent	Negligible	Minor	Probable	n/a	Minor; Probable
	Entrainment by turbines and water abstractions.	i. Injury and mortality. ii. Decreased fitness.	Direct	Long term/ intermittent	Negligible	Insignificant	High	n/a	Insignificant; Probable
	N.B. Any effects on spawning have been excluded from the assessment as it occurs outside the area of impact.								

Table 9.29 Summary of potential environmental effects on shad (*Alosa alosa* and *Alosa fallax*)

Valued Ecological Receptor	Impact	Characterisation of impact	Direct/ Indirect	Frequency	Magnitude	Significance without mitigation	Confidence	Mitigation Code (see Table 9.27)	Residual Significance and Confidence Level (adverse unless stated otherwise)
Shad (<i>Alosa alosa</i> and <i>Alosa fallax</i>)	Construction Phase								
	Increases in suspended sediment and deposition.	i. Behavioural disturbance.	Direct	Long term/ intermittent	Negligible	Minor	Probable	A	Insignificant; Probable
		ii. Injury and mortality.							
	Increases in underwater noise and vibration.	i. Behavioural disturbance.	Direct	Long term / intermittent	Medium	Major	High	B	Minor; High
		ii. Injury and mortality.							
	Increase in artificial light emissions.	i. Behavioural disturbance.	Direct	Long term / intermittent	Low	Minor	Probable	I	Insignificant; Probable
	Habitat modification.	i. Loss/ disturbance to foraging habitat.	Direct	Long term/ continuous	Negligible	Minor	Probable	C	Insignificant; Probable
		ii. Gain of foraging habitat.							
	Habitat loss due to dewatering of temporary cofferdam.	i. Injury and mortality due to dewatering.	Direct	Long term/ intermittent	Neutral	No impact	High	n/a	No impact; High
		ii. Reduced fitness.							
	Entrainment from draghead	i. Injury and mortality.	Direct	Long term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
	Operational phase								
	Increases in suspended sediment and deposition.	i. Behavioural disturbance.	Direct	Long term/ intermittent	Negligible	Minor	Probable	A	Insignificant; Probable
		ii. Injury and mortality.							
	Habitat fragmentation and isolation.	i. Delays to migration.	Direct	Long term/ continuous	Negligible	Minor	Probable	E	Minor; Probable
		ii. Increased energetic costs.							
		iii. Fragmentation of migratory routes.							
	Habitat modification.	i. Loss/ disturbance to foraging habitat.	Direct	Long term/ continuous	Negligible	Minor	Probable	C	Insignificant; Probable
		ii. Gain of foraging habitat.							
	Increased predation.	i. Injury and mortality	Direct	Long term/ intermittent	Positive - Negligible	Minor	Probable	n/a	Minor Positive; Probable
		ii. Decreased fitness.							
	Entrainment from draghead	i. Injury and mortality.	Direct	Long term/ intermittent	Low	Minor	Probable	n/a	Minor; Probable
		ii. Reduced fitness.							

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Valued Ecological Receptor	Impact	Characterisation of impact	Direct/ Indirect	Frequency	Magnitude	Significance without mitigation	Confidence	Mitigation Code (see Table 9.27)	Residual Significance and Confidence Level (adverse unless stated otherwise)
	Entrainment and injury from turbines.	i. Injury and mortality. ii. Decreased fitness	Direct	Long term/ intermittent	Negligible	Minor	High	F	Insignificant; High
	Waterborne noise and vibration from turbines.	i. Behavioural disturbance.	Direct	Long term/ intermittent	Negligible	Minor	High	n/a	Minor; High
	Fluctuations in Lagoon water levels.	i. Behavioural disturbance. ii. Injury and mortality.	Direct	Long term/ intermittent	Neutral	No impact	High	n/a	No impact; High
	Entrainment and injury from sluices	i. Injury and mortality. ii. Decreased fitness	Direct	Long term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
	Increases in artificial light emissions.	i. Behavioural disturbance.	Direct	Long term/ continuous	Low	Minor	Probable	I	Insignificant; Probable
	Deterioration in water quality.	i. Behavioural disturbance. ii. Increased mortality	Direct	Long term/ intermittent	Neutral	No impact	High	n/a	No impact; High
	Creation of EMFs.	i. Behavioural avoidance.	Direct	long term/ intermittent	Neutral	No impact	High	n/a	No impact; High
	Waterborne noise and vibration from recreational activities.	i. Behavioural disturbance.	Direct	Long term/ intermittent	Negligible	Minor	High	H	Minor; High
	Increased pressure on fish populations as a result of recreational angling.	i. Increased mortality.	Direct	Long term/ intermittent	Negligible	Minor	Uncertain	n/a	Minor; Uncertain
	Decommissioning Phase								
	Increases in suspended sediment and deposition.	i. Behavioural disturbance. ii. Injury and mortality.	Direct	Short term/ intermittent	Negligible	Minor	Probable	A	Insignificant; Probable
	Increases in underwater noise and vibration.	i. Behavioural disturbance. ii. Injury and mortality.	Direct	Short term/ intermittent	Negligible	Minor	Probable	n/a	Insignificant; Probable
	Improved connectivity between the habitat within and outside of the Lagoon.	i. Increased access to foraging grounds	Direct	Long term/ continuous	Positive - Negligible	Minor	Probable	C	Minor Positive; Probable

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Valued Ecological Receptor	Impact	Characterisation of impact	Direct/ Indirect	Frequency	Magnitude	Significance without mitigation	Confidence	Mitigation Code (see Table 9.27)	Residual Significance and Confidence Level (adverse unless stated otherwise)
	Cumulative								
	Increases in suspended sediment and deposition.	i. Behavioural disturbance. ii. Injury and mortality.	Direct	Short term/ intermittent	Negligible	Minor	Probable	A	Insignificant; Probable
	Increases in underwater noise and vibration.	i. Behavioural disturbance. ii. Injury and mortality.	Direct	Short term/ intermittent	Negligible	Minor	Probable	n/a	Insignificant; Probable
	Habitat modification.	i. Loss/disturbance to foraging habitat. i. Gain of foraging habitat.	Direct	Short term/ intermittent	Negligible	Minor	Probable	C	Insignificant; Probable
			Direct	Short term/ intermittent	Positive - Negligible	Minor	Probable	n/a	Minor Positive; Probable
	Habitat fragmentation and isolation.	i. Delays to migration. ii. Increased energetic costs. iii. Fragmentation of migratory routes.	Direct	Long term/ Continuous	Negligible	Minor	Probable	E	Insignificant; Probable
	Increased predation.	i. Injury and mortality ii. Reduced fitness	Direct	Long term/ intermittent	Negligible	Minor	Probable	n/a	Minor; Probable
	Entrainment by turbines and water abstractions.	i. Injury and mortality ii. Decreased fitness	Direct	Long term/ intermittent	Neutral	No impact	Probable	n/a	No impact; Probable

N.B. Any effects on spawning have been excluded from the assessment as it occurs outside the area of impact.

Table 9.30 Summary of potential effects on sea lamprey *Petromyzon marinus*

Valued Ecological Receptor	Impact	Characterisation of impact	Direct/ Indirect	Frequency	Magnitude	Significance without mitigation	Confidence	Mitigation Code (see Table 9.27)	Residual Significance and Confidence Level (adverse unless stated otherwise)
Sea lamprey <i>Petromyzon marinus</i>	Construction phase								
	Increases in suspended sediment and deposition.	i. Behavioural disturbance.	Direct	Long term/ intermittent	Negligible	Minor	Probable	A	Insignificant; Probable
		ii. Injury and mortality.							
	Increases in underwater noise and vibration.	i. Behavioural disturbance.	Direct	Long term/ intermittent	Negligible	Minor	High	B	Insignificant; High
		ii. Injury and mortality.							
	Increases in artificial light emissions	i. Behavioural disturbance.	Direct	Long term/ intermittent	Negligible	Minor	Uncertain	I	Minor; Uncertain
	Habitat modification.	i. Loss/ disturbance to foraging habitat.	Direct	Long term/ continuous	Negligible	Minor	Probable	C	Insignificant; Probable
		i. Gain of foraging habitat.							
	Habitat loss due to dewatering of cofferdam.	i. Injury and mortality due to dewatering.	Direct	Long term/ continuous	Negligible	Minor	Probable	D	Insignificant; Probable
	Entrainment from draghead	i. Injury and mortality ii. Reduced fitness	Direct	Long term/ Intermittent	Negligible	Insignificant	Uncertain	n/a	Insignificant; Uncertain
	Operational phase								
	Increases in suspended sediment and deposition.	i. Behavioural disturbance.	Direct	Long term/ intermittent	Negligible	Minor	Probable	A	Insignificant; Probable
		ii. Injury and mortality.							
	Habitat fragmentation and isolation.	i. Delays to migration.	Direct	Long term/ continuous	Negligible	Minor	Probable	E	Minor; Probable
		ii. Increased energetic costs.							
		iii. Fragmentation of migratory routes.							
	Habitat modification.	i. Loss/disturbance to foraging habitat.	Direct	Long term/ continuous	Negligible	Minor	Probable	C	Insignificant; Probable
		i. Gain of foraging habitat.							
	Increased	i. Injury and mortality.	Direct	Long term/	Low	Minor (juvenile)	Uncertain	n/a	Minor; Uncertain (juvenile)



Tidal Lagoon Swansea Bay plc

Valued Ecological Receptor	Impact	Characterisation of impact	Direct/ Indirect	Frequency	Magnitude	Significance without mitigation	Confidence	Mitigation Code (see Table 9.27)	Residual Significance and Confidence Level (adverse unless stated otherwise)
	predation	ii. Decreased fitness.		intermittent	Low	Minor (adult)	Uncertain		Minor; Uncertain (adult)
	Entrainment from draghead	i. Injury and mortality	Direct	Long term/ intermittent	Negligible	Insignificant	Uncertain	n/a	Insignificant; Uncertain
	Entrainment and injury from the turbines.	ii. Reduced fitness	Direct	Long term/ intermittent	Negligible	Insignificant (juvenile)	Probable	n/a	Insignificant; Probable (juvenile)
		ii. Reduced fitness					Probable	F	Minor; Probable (adult)
	Waterborne noise and vibration from turbines.	i. Behavioural disturbance.	Direct	Long term/ intermittent	Negligible	Insignificant	High	n/a	Insignificant; High
	Fluctuations in Lagoon water levels.	i. Behavioural disturbance.	Direct	Long term/ intermittent	Negligible	Insignificant	High	n/a	Insignificant; High
		ii. Injury and mortality.	Direct	Long term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
	Entrainment and injury from sluices.	i. Injury and mortality	Direct	Long term/ intermittent	Negligible	Insignificant	Uncertain	I	Insignificant; Uncertain
	Increases in artificial light emissions	ii. Reduced fitness	Direct	Long term/ continuous	Negligible	Minor	Uncertain		
	Deterioration in water quality.	i. Behavioural disturbance.	Direct	Long term/ intermittent	Neutral	No impact	High	n/a	No impact; High
		ii. Increased mortality	Direct	Long term/ intermittent	Neutral	No impact	High	n/a	No impact; High
	Creation of EMFs.	i. Behavioural avoidance.	Direct	long term/ intermittent	Neutral	No impact	High	n/a	Insignificant; High
	Waterborne noise and vibration from recreational activities.	ii. Behavioural disturbance.	Direct	Long term/ intermittent	Negligible	Insignificant	High	n/a	
	Decommissioning phase								
	Increases in suspended sediment and deposition.	i. Behavioural disturbance.	Direct	Short term/ intermittent	Negligible	Minor	Probable	A	Insignificant; Probable
		ii. Injury and mortality.							
	Increase in underwater noise and vibration	i. Behavioural disturbance.	Direct	Short term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
		ii. Injury and mortality.							

Tidal Lagoon Swansea Bay plc

Valued Ecological Receptor	Impact	Characterisation of impact	Direct/ Indirect	Frequency	Magnitude	Significance without mitigation	Confidence	Mitigation Code (see Table 9.27)	Residual Significance and Confidence Level (adverse unless stated otherwise)
	Improved connectivity between the habitat within and outside of the Lagoon.	i. Increased access to foraging grounds	Direct	Long term/ continuous	Positive - Negligible	Minor	Probable	n/a	Minor Positive; Probable
Cumulative									
	Increases in suspended sediment and deposition.	i. Behavioural disturbance. ii. Injury and mortality.	Direct	Long term/ intermittent	Negligible	Minor	Probable	A	Insignificant; Probable
	Increases in underwater noise and vibration.	i. Behavioural disturbance. i. Injury and mortality.	Direct	Long term/ intermittent	Negligible	Minor	Probable	B	Insignificant; Probable
	Habitat modification.	i. Loss/disturbance to foraging habitat. i. Gain of foraging habitat.	Direct	Long term/ intermittent	Negligible	Minor	Probable	C	Insignificant; Probable
		i. Delays to migration. ii. Increased energetic costs. iii. Fragmentation of migratory routes.	Direct	Short term/ intermittent	Positive - Negligible	Minor	Probable	n/a	Minor Positive; Probable
	Habitat fragmentation and isolation	i. Delays to migration. ii. Increased energetic costs. iii. Fragmentation of migratory routes.	Direct	Long term/ continuous	Negligible	Minor	Probable	E	Insignificant; Probable
	Increased predation	i. Injury and mortality. ii. Reduced fitness.	Direct	Long term/ intermittent	Negligible	Minor	Probable	n/a	Minor; Probable
	Entrapment by turbines and water abstractions.	i. Injury and mortality. ii. Decreased fitness.	Direct	Long term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable

N.B. Any effects on spawning have been excluded from the assessment as it occurs outside the area of impact. The effects of recreational fishing for Sea lamprey are not assessed as they are not a target species.

Table 9.31 Summary of potential environmental effects on river lamprey *Lampetra fluviatilis*

Valued Ecological Receptor	Impact	Characterisation of impact	Direct/ Indirect	Frequency	Magnitude	Significance without mitigation	Confidence	Mitigation Code (see Table 9.27)	Residual Significance and Confidence Level (adverse unless stated otherwise)
River lamprey <i>Lampetra fluviatilis</i>	Construction phase								
	Increases in suspended sediment and deposition.	i. Behavioural disturbance.	Direct	Long term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
		ii. Injury and mortality.							
	Increases in underwater noise and vibration.	i. Behavioural disturbance.	Direct	Long term/ intermittent	Negligible	Insignificant	High	n/a	Insignificant; High
		ii. Injury and mortality.							
	Increases in artificial light emissions	i. Behavioural disturbance.	Direct	Long term/ intermittent	Negligible	Insignificant	Uncertain	n/a	Insignificant; Uncertain
	Habitat modification.	i. Loss/ disturbance to foraging habitat.	Direct	Long term/ continuous	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
		ii. Gain of foraging habitat.		Long term/ continuous					
	Habitat loss due to dewatering of cofferdam.	i. Injury and mortality due to dewatering.	Direct	Long term/ continuous	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
	Entrainment from draghead	i. Injury and mortality ii. Reduced fitness	Direct	Long term/ intermittent	Negligible	Insignificant	Uncertain	n/a	Insignificant; Uncertain
	Operational phase								
	Increases in suspended sediment and deposition.	i. Behavioural disturbance.	Direct	Long term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
		ii. Injury and mortality.							
	Habitat fragmentation and isolation.	i. Delays to migration.	Direct	Long term/ continuous	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
		ii. Increased energetic costs.							
		iii. Fragmentation of migratory routes.							
	Habitat modification.	i. Loss/disturbance to foraging habitat.	Direct	Long term/ continuous	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
		ii. Gain of foraging habitat.							
	Increased predation	i. Injury and mortality. ii. Decreased fitness.	Direct	Long term/ intermittent	Low	Minor (juvenile)	Uncertain	n/a	Minor; Uncertain (juvenile)



Tidal Lagoon Swansea Bay plc

Valued Ecological Receptor	Impact	Characterisation of impact	Direct/ Indirect	Frequency	Magnitude	Significance without mitigation	Confidence	Mitigation Code (see Table 9.27)	Residual Significance and Confidence Level (adverse unless stated otherwise)
					Low	Minor (adult)	Uncertain		Minor; Uncertain (adult)
	Entrainment from draghead	i. Injury and mortality	Direct	Long term/ intermittent	Negligible	Insignificant	Uncertain	n/a	Insignificant; Uncertain
		ii. Reduced fitness							
	Entrainment and injury from the turbines.	i. Injury and mortality.	Direct	Long term/ intermittent	Negligible	Insignificant (juvenile)	Probable	n/a	Insignificant; Probable (juvenile)
		ii. Decreased fitness				Minor (adult)	Probable	F	Minor; Probable (adult)
	Waterborne noise and vibration from turbines.	i. Behavioural disturbance.	Direct	Long term/ intermittent	Negligible	Insignificant	High	n/a	Insignificant; High
	Fluctuations in Lagoon water levels.	i. Behavioural disturbance.	Direct	Long term/ intermittent	Negligible	Insignificant	High	n/a	Insignificant; High
		ii. Injury and mortality.							
	Entrainment and injury from sluices	i. Injury and mortality	Direct	Long term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
		ii. Reduced fitness							
	Increases in artificial light emissions	i. Behavioural disturbance.	Direct	Long term/ continuous	Negligible	Insignificant	Uncertain	n/a	Insignificant; Uncertain
	Deterioration in water quality.	i. Behavioural disturbance.	Direct	Long term/ intermittent	Neutral	No impact	High	n/a	No impact; High
ii. Increased mortality									
Creation of EMFs.	i. Behavioural avoidance.	Direct	long term/ intermittent	Neutral	No impact	High	n/a	No impact; High	
Waterborne noise and vibration from recreational activities.	i. Behavioural disturbance.	Direct	Long term/ intermittent	Negligible	Insignificant	High	n/a	Insignificant; High	
Decommissioning phase									
Increases in suspended sediment and deposition.	i. Behavioural disturbance.	Direct	Short term/ intermittent	Negligible	Insignificant	Probable	n/a	insignificant; Probable	
	ii. Injury and mortality.								
Increase in underwater noise and vibration	i. Behavioural disturbance.	Direct	Short term/ intermittent	Negligible	Insignificant	Probable	n/a	insignificant; Probable	
	ii. Injury and mortality.								

Tidal Lagoon Swansea Bay plc

Valued Ecological Receptor	Impact	Characterisation of impact	Direct/ Indirect	Frequency	Magnitude	Significance without mitigation	Confidence	Mitigation Code (see Table 9.27)	Residual Significance and Confidence Level (adverse unless stated otherwise)
	Improved connectivity between the habitat within and outside of the Lagoon.	i. Increased access to foraging grounds	Direct	Long term/ continuous	Positive - Negligible	Insignificant	Probable	n/a	Insignificant Positive; Probable
Cumulative									
	Increases in suspended sediment and deposition.	i. Behavioural disturbance. ii. Injury and mortality.	Direct	Long term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
	Increases in underwater noise and vibration.	ii. Behavioural disturbance. iii. Injury and mortality.	Direct	Long term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
	Habitat modification.	i. Loss/disturbance to foraging habitat. i. Gain of foraging habitat.	Direct	Long term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
		i. Delays to migration. ii. Increased energetic costs. iii. Fragmentation of migratory routes.	Direct	Short term/ intermittent	Positive - Negligible	Insignificant	Probable	n/a	Insignificant Positive; Probable
	Habitat fragmentation and isolation	i. Delays to migration. ii. Increased energetic costs. iii. Fragmentation of migratory routes.	Direct	Long term/ continuous	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
	Increased predation	i. Injury and mortality. ii. Reduced fitness.	Direct	Long term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
	Entrainment by turbines and water abstractions.	i. Injury and mortality. ii. Decreased fitness.	Direct	Long term/ intermittent	Negligible	Insignificant	High	n/a	Insignificant; Probable

N.B. Any effects on spawning have been excluded from the assessment as it occurs outside the area of impact. The effects of recreational fishing for River lamprey are not assessed as they are not a target species.

Table 9.32 Summary of potential environmental effects on Atlantic salmon *Salmo salar*. Note that some impacts are not considered in this table

Valued Ecological Receptor	Impact	Characterisation of impact	Direct/ Indirect	Frequency	Magnitude	Significance without mitigation	Confidence	Mitigation code (see Table 9.27)	Residual Significance and Confidence Level (adverse impact unless otherwise stated)
Atlantic salmon <i>Salmo salar</i>	Construction phase								
	Increases in suspended sediment and deposition.	i. Behavioural disturbance. ii. Injury and mortality.	Direct	Long term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
	Increases in underwater noise and vibration.	i. Behavioural disturbance. ii. Injury and mortality.	Direct	Long term/ intermittent	Low	Minor	High	B	Insignificant; High
	Increases in artificial light emissions.	i. Behavioural disturbance.	Direct	Long term/ intermittent	Negligible	Insignificant	Uncertain	n/a	Insignificant; Uncertain
	Habitat loss due to dewatering of cofferdam.	i. Injury and mortality during dewatering.	Direct	Long term/ continuous	Negligible	Insignificant	High	n/a	Insignificant; High
	Entrainment from draghead	i. Injury and mortality ii. Reduced fitness	Direct	Long term/ Intermittent	Negligible	Insignificant	High	n/a	Insignificant; High
	Operational phase								
	Increases in suspended sediment and deposition.	i. Injury and mortality ii. Behavioural disturbance.	Direct	Long term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
	Habitat fragmentation and isolation.	i. Delays to migration. ii. Increased energetic costs. iii. Fragmentation of migratory routes.	Direct	Long term/ continuous	Low	Minor	Probable	E	Minor; Probable
	Increased predation.	i. Injury and mortality ii. Decreased fitness.	Direct	Long term/ intermittent	Low	Minor (smolts)	Uncertain	n/a	Minor (smolts); Uncertain
	Entrainment from draghead	i. Injury and mortality ii. Reduced fitness	Direct	Long term/ Intermittent	Negligible	Insignificant (adult)	Uncertain	n/a	Insignificant (adult); Uncertain
						Insignificant	High	n/a	Insignificant; High

Tidal Lagoon Swansea Bay plc

Valued Ecological Receptor	Impact	Characterisation of impact	Direct/ Indirect	Frequency	Magnitude	Significance without mitigation	Confidence	Mitigation code (see Table 9.27)	Residual Significance and Confidence Level (adverse impact unless otherwise stated)
	Entrainment and injury from turbines.	i. Injury and mortality.	Direct	Long term/ intermittent	Negligible	Insignificant (smolts)	High	n/a	Insignificant; High (smolt)
		ii. Decreased fitness.			Negligible	Insignificant (adult)	High		Insignificant; High (adult)
	Waterborne noise and vibration from turbines.	i. Behavioural disturbance.	Direct	Long term/ intermittent	Negligible	Insignificant	High	n/a	Insignificant; High
	Fluctuations in Lagoon water levels.	i. Behavioural disturbance.	Direct	Long term/ intermittent	Neutral	No impact	High	n/a	No impact; High
	Entrainment and injury from sluices	ii. Injury and mortality.	Direct	Long term/ intermittent	Negligible	Insignificant	High	n/a	Insignificant; High
		i. Injury and mortality							
	Increases in artificial light emissions.	ii. Reduced fitness	Direct	Long term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
		i. Behavioural disturbance.							
	Deterioration in water quality.	i. Behavioural disturbance.	Direct/ Indirect	Long term/ intermittent	Neutral	No impact	High	n/a	No impact; High
	Creation of EMFs.	ii. Increased mortality	Direct	long term/ intermittent	Neutral	No impact	Probable	n/a	No impact; Probable
		i. Behavioural avoidance.							
	Waterborne noise and vibration from recreational activities.	i. Behavioural disturbance.	Direct	long term/ intermittent	Negligible	Insignificant	High	n/a	Insignificant; High
	Increased pressure on fish populations as a result of recreational angling.	i. Increased mortality.	Direct	Long term/ intermittent	Negligible	Insignificant	Uncertain	n/a	Insignificant; Uncertain
	Decommissioning phase								
	Increases in suspended sediment and deposition.	i. Behavioural disturbance.	Direct	Short term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
		ii. Injury and mortality.							

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Valued Ecological Receptor	Impact	Characterisation of impact	Direct/ Indirect	Frequency	Magnitude	Significance without mitigation	Confidence	Mitigation code (see Table 9.27)	Residual Significance and Confidence Level (adverse impact unless otherwise stated)
	Increases in underwater noise and vibration.	i. Behavioural avoidance. ii. Injury and mortality	Direct	Short term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
	Cumulative								
	Increases in suspended sediment and deposition.	i. Behavioural disturbance. ii. Injury and mortality.	Direct	Long term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
	Increases in underwater noise and vibration.	i. Behavioural disturbance. ii. Injury and mortality.	Direct	Long term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
	Habitat fragmentation and isolation.	i. Delays to migration. ii. Increased energetic costs. iii. Fragmentation of migratory routes.	Direct	Long term/ continuous	Negligible	Insignificant	Uncertain	n/a	Insignificant; Uncertain
	Increased predation.	i. Injury and mortality ii. Reduced fitness	Direct	Long term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
	Entrainment by turbines and water abstractions.	i. Injury and mortality ii. Reduced fitness	Direct	Long term/ intermittent	Negligible	Insignificant	High	n/a	Insignificant; High
	N.B. Habitat modification has not been included for salmon as they do not feed within coastal waters. Any effects on spawning have been excluded from the assessment as it occurs outside the area of impact.								

Table 9.33 Summary of potential environmental effects on common sole *Solea solea*

Valued Ecological Receptor	Impact	Characterisation of impact	Direct/ Indirect	Frequency	Magnitude	Significance without mitigation	Confidence	Mitigation Code (see Table 9.27)	Residual Significance and Confidence Level (adverse unless stated otherwise)
Common sole <i>Solea solea</i>	Construction phase								
	Increases in suspended sediment and deposition.	i. Smother spawning grounds and benthic fauna.	Direct	Long term/ intermittent	Negligible	Insignificant	High	n/a	Insignificant; High
		ii. Impact on larval/juvenile fish.							
		iii. Behavioural disturbance.							
		iv. Injury and mortality.							
	Increases in underwater noise and vibration.	i. Behavioural disturbance.	Direct	Long term/ intermittent	Negligible	Insignificant	High	n/a	Insignificant; High
		ii. Injury and mortality.							
	Increases in artificial light emissions	i. Behavioural disturbance.	Direct	Long term/ intermittent	Negligible	Insignificant	Uncertain	n/a	Insignificant; Uncertain
	Habitat modification.	i. Loss/disturbance to spawning habitat	Direct	Long term/ continuous	Low	Minor	Probable	C	Minor; Probable
		ii. Loss/disturbance to foraging habitat.							
	Habitat loss due to dewatering of cofferdam.	i. Gain of spawning habitat.	Direct	Long term/ continuous	Positive - Negligible	Insignificant	Probable	n/a	Insignificant Positive; Probable
		ii. Gain of foraging habitat.							
	Entrainment from draghead	i. Injury and mortality due to dewatering.	Direct	Long term/ continuous	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
		ii. Reduced fitness							
	Operational phase								
	Increases in suspended sediment and deposition.	i. Smother spawning grounds and benthic fauna.	Direct	Long term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
		ii. Impact on larval/ juvenile fish.							
		iii. Behavioural disturbance.							
		iv. Injury and mortality.							



Tidal Lagoon Swansea Bay plc

Valued Ecological Receptor	Impact	Characterisation of impact	Direct/ Indirect	Frequency	Magnitude	Significance without mitigation	Confidence	Mitigation Code (see Table 9.27)	Residual Significance and Confidence Level (adverse unless stated otherwise)
	Habitat modification.	i. Loss/disturbance to spawning habitat.	Direct	Long term/continuous	Low	Minor	Probable	C	Minor; Probable
		ii. Loss/disturbance to foraging habitat.							
		i. Gain of spawning habitat.	Direct	Long term/continuous	Positive - Negligible	Insignificant	Probable	n/a	Insignificant Positive; Probable
		ii. Gain of foraging habitat.							
	Increased predation	i. Injury and mortality.	Direct	Long term/intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
		ii. Decreased fitness.							
	Entrainment from draghead	i. Injury and mortality	Direct	Long term/Intermittent	Negligible	Insignificant	Uncertain	n/a	Insignificant; Uncertain
		ii. Reduced fitness							
	Entrainment and injury from the turbines.	i. Injury and mortality.	Direct	Long term/intermittent	Negligible	Insignificant	High	n/a	Insignificant; High
		ii. Decreased fitness							
	Waterborne noise and vibration from turbines.	i. Behavioural disturbance.	Direct	Long term/intermittent	Negligible	Insignificant	High	n/a	Insignificant; High
		ii. Injury and mortality.							
	Fluctuations in Lagoon water levels.	i. Behavioural disturbance.	Direct	Long term/intermittent	Negligible	Insignificant	High	n/a	Insignificant; High
		ii. Injury and mortality.							
	Entrainment and injury from sluices	i. Injury and mortality	Direct	Long term/intermittent	Negligible	Insignificant	High	n/a	Insignificant; High
		ii. Reduced fitness							
	Increases in artificial light emissions	i. Behavioural disturbance.	Direct	Long term/continuous	Negligible	Insignificant	Uncertain	n/a	Insignificant; Uncertain
		ii. Increased mortality							
	Deterioration in water quality.	i. Behavioural disturbance.	Direct	Long term/intermittent	Neutral	No impact	High	n/a	No impact; High
		ii. Increased mortality							
	Creation of EMFs.	i. Behavioural avoidance.	Direct	long term/intermittent	Neutral	No impact	High	n/a	No impact; High
		ii. Behavioural avoidance.							
	Waterborne noise and vibration from recreational activities.	i. Behavioural disturbance.	Direct	Long term/intermittent	Negligible	Insignificant	High	n/a	Insignificant; High
		ii. Behavioural disturbance.							

Tidal Lagoon Swansea Bay plc

Valued Ecological Receptor	Impact	Characterisation of impact	Direct/ Indirect	Frequency	Magnitude	Significance without mitigation	Confidence	Mitigation Code (see Table 9.27)	Residual Significance and Confidence Level (adverse unless stated otherwise)
	Increased pressure on fish populations as a result of recreational angling.	i. Increased mortality.	Direct	Long term/ intermittent	Low	Minor	Uncertain	n/a	Minor; Uncertain
	Decommissioning phase								
	Increases in suspended sediment and deposition.	i. Behavioural disturbance.	Direct	Short term/ intermittent	Negligible	Insignificant	Probable	n/a	insignificant; Probable
		ii. Injury and mortality.							
	Increase in underwater noise and vibration	i. Behavioural disturbance.	Direct	Short term/ intermittent	Negligible	Insignificant	Probable	n/a	insignificant; Probable
		ii. Injury and mortality.							
	Improved connectivity between the habitat within and outside of the Lagoon.	i. Increased access to spawning grounds.	Direct	Long term/ continuous	Positive - Low	Minor	Probable	n/a	Minor Positive; Probable
		ii. Increased access to foraging grounds.							
	Cumulative								
	Increases in suspended sediment and deposition.	i. Smother spawning grounds and benthic fauna.	Direct	Long term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
		ii. Impact on larval/juvenile fish.							
		iii. Behavioural disturbance.							
		iv. Injury and mortality.							
Increases in underwater noise and vibration.	i. Behavioural disturbance.	Direct	Long term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable	
	ii. Injury and mortality.								
Habitat modification.	i. Loss/disturbance to spawning habitat.	Direct	Long term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable	
	ii. Loss/disturbance to foraging habitat.								



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Valued Ecological Receptor	Impact	Characterisation of impact	Direct/ Indirect	Frequency	Magnitude	Significance without mitigation	Confidence	Mitigation Code (see Table 9.27)	Residual Significance and Confidence Level (adverse unless stated otherwise)
		i. Gain of spawning habitat. ii. Gain of foraging habitat.	Direct	Short term/ intermittent	Positive - Negligible	Insignificant	Probable	n/a	Insignificant Positive; Probable
	Increased predation	i. Injury and mortality. ii. Reduced fitness.	Direct	Long term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
	Entrainment by turbines and water abstractions.	i. Injury and mortality. ii. Decreased fitness.	Direct	Long term/ intermittent	Neutral	No impact	High	n/a	No impact; High
	N.B. Habitat fragmentation and isolation has not been assessed for Common sole; nevertheless, disturbance to foraging habitat has been assessed under habitat modification.								

Table 9.34 Summary of potential environmental effects on sea trout *Salmo trutta*

Valued Ecological Receptor	Impact	Characterisation of impact	Direct/ Indirect	Frequency	Magnitude	Significance without mitigation	Confidence	Mitigation code (see Table 9.27)	Residual Significance and Confidence Level (adverse unless stated otherwise)
Sea trout <i>Salmo trutta</i>	Construction Phase								
	Increases in suspended sediment and deposition.	i. Behavioural disturbance.	Direct	Long term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
		ii. Injury and mortality.							
	Increases in underwater noise and vibration.	i. Behavioural disturbance.	Direct	Long term/ intermittent	Low	Minor	High	B	Insignificant; High
		ii. Injury and mortality.							
	Increases in artificial light emissions.	i. Behavioural disturbance.	Direct	Long term/ intermittent	Negligible	Insignificant	Uncertain	n/a	Insignificant; Uncertain
		ii. Loss/disturbance to foraging habitat.							
	Habitat modification.	i. Loss/disturbance to foraging habitat.	Direct	Long term/ continuous	Medium	Moderate	Uncertain	C	Minor; Uncertain
		ii. Gain of foraging habitat.							
	Habitat loss due to dewatering of cofferdam.	i. Injury and mortality due to dewatering.	Direct	Long term/ continuous	Negligible	Insignificant	High	n/a	Insignificant; High
		ii. Injury and mortality due to dewatering.							
	Entrainment from draghead	i. Injury and mortality	Direct	Long term/ Intermittent	Negligible	Insignificant	High	n/a	Insignificant; High
		ii. Reduced fitness							
	Operational phase								
	Increases in suspended sediment and deposition.	i. Behavioural disturbance.	Direct	Long term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
		ii. Injury and mortality.							
Habitat fragmentation and isolation.	i. Delays to migration.	Direct	Long term/ continuous	Low	Minor	Probable	E	Minor; Probable	
	ii. Increased energetic costs.								
	iii. Fragmentation of migratory routes.								
Habitat modification.	i. Loss/disturbance to foraging habitat.	Direct	Long term/ continuous	Medium	Moderate	Uncertain	C	Minor; Uncertain	
	ii. Gain of foraging habitat.								
Increased predation.	i. Injury and mortality	Direct	Long term/ intermittent	Low	Minor (smolt)	Uncertain	n/a	Minor; Uncertain (smolt)	
	ii. Reduced fitness.								
				Negligible	Insignificant (adult)	Uncertain		Insignificant; Uncertain (adult)	

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Valued Ecological Receptor	Impact	Characterisation of impact	Direct/ Indirect	Frequency	Magnitude	Significance without mitigation	Confidence	Mitigation code (see Table 9.27)	Residual Significance and Confidence Level (adverse unless stated otherwise)
	Entrainment from draghead	i. Injury and mortality ii. Reduced fitness	Direct	Long term/ Intermittent	Negligible	Insufficient	Uncertain	n/a	Insufficient; Uncertain
	Entrainment and injury from turbines.	i. Injury and mortality;	Direct	Long term/ intermittent	Negligible	Insufficient (smolt)	High	F	Insufficient; High (smolt)
		ii. Reduced fitness			Medium	Moderate (adult)	High		Minor; High (adult)
	Waterborne noise and vibration from turbines.	i. Behavioural disturbance. ii. Injury and mortality.	Direct	Long term/ continuous	Negligible	Insufficient	High	n/a	Insufficient; Certain
	Fluctuations in Lagoon water levels	i. Behavioural disturbance. ii. Injury and mortality.	Direct	Long term/ intermittent	Neutral	No impact	High	n/a	No impact; High
	Entrainment and injury from sluices.	i. Injury and mortality ii. Reduced fitness	Direct	Long term/ Intermittent	Negligible	Insufficient	High	n/a	Insufficient; High
	Increases in artificial light emissions.	i. Behavioural disturbance.	Direct	Long term/ continuous	Negligible	Insufficient	Probable	n/a	Insufficient; Probable
	Deterioration in water quality.	i. Behavioural disturbance. ii. Increased mortality	Direct	Long term/ intermittent	Neutral	No impact	High	n/a	No impact; High
	Creation of EMFs.	i. Behavioural disturbance.	Direct	long term/ intermittent	Neutral	No impact	Probable	n/a	No impact; Probable
	Waterborne noise and vibration from recreational activities.	i. Behavioural disturbance.	Direct	Long term/ continuous	Negligible	Insufficient	High	n/a	Insufficient; High
	Increased pressure on fish populations as a result of recreational angling.	i. Increased mortality.	Direct	Long term/ intermittent	Negligible	Insufficient	Uncertain	n/a	Insufficient; Uncertain
	Decommissioning phase								
	Increases in suspended sediment and deposition.	i. Behavioural disturbance.	Direct	Short term/ intermittent	Negligible	Insufficient	Probable	n/a	Insufficient; Probable
		ii. Injury and mortality.							

Tidal Lagoon Swansea Bay plc

Valued Ecological Receptor	Impact	Characterisation of impact	Direct/ Indirect	Frequency	Magnitude	Significance without mitigation	Confidence	Mitigation code (see Table 9.27)	Residual Significance and Confidence Level (adverse unless stated otherwise)
	Increases in under water noise and vibration	i. Behavioural disturbance. ii. Injury and mortality.	Direct	Short term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
	Improved connectivity between the habitat within and outside of the Lagoon.	i. Increased access to foraging grounds.	Direct	Long term/ continuous	Positive - Low	Minor	Uncertain	n/a	Minor Positive; Uncertain
	Cumulative								
	Increases in suspended sediment/deposition.	i. Behavioural disturbance. ii. Injury and mortality.	Direct	Long term/ intermittent	Negligible	Insignificant	Probable	n/a	insignificant; Probable
	Increases in underwater noise and vibration.	i. Behavioural disturbance. ii. Injury and mortality.	Direct	Long term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
	Habitat modification.	i. Loss/disturbance to foraging habitat.	Direct	Long term/ intermittent	Negligible	Insignificant	Uncertain	n/a	Insignificant; Uncertain
		i. Gain of foraging habitat.	Direct	Short term/ intermittent	Negligible	Insignificant	Uncertain	n/a	Insignificant; Uncertain
	Habitat fragmentation and isolation.	i. Delays to migration. ii. Increased energetic costs. iii. Fragmentation of migratory routes.	Direct	Long term/ Continuous	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
	Increased predation.	i. Injury and mortality ii. Reduced fitness	Direct	Long term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
	Entrainment by turbines and water abstractions.	i. Injury and mortality ii. Decreased fitness	Direct	Long term/ Intermittent	Negligible	Insignificant	High	n/a	Insignificant; High

N.B. Any effects on spawning have been excluded from the assessment as it occurs outside the area of impact.

Table 9.35 Summary of potential environmental effects on herring *Clupea harengus*

Valued Ecological Receptor	Impact	Characterisation of impact	Direct/ Indirect	Frequency	Magnitude	Significance without mitigation	Confidence	Mitigation Code (see Table 9.27)	Residual Significance and Confidence Level (adverse unless stated otherwise)
Herring <i>Clupea harengus</i>	Construction Phase								
	Increases in suspended sediment and deposition.	i. Smother spawning grounds	Direct	Long term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
		ii. Impacts on larval/juvenile fish.							
		iii. Behavioural disturbance.							
		iv. Injury and mortality.							
	Increases in underwater noise and vibration.	i. Behavioural disturbance.	Direct	Long term / intermittent	Medium	Moderate	High	B	Minor; High
		ii. Injury and mortality.							
	Increase in artificial light emissions.	i. Behavioural disturbance.	Direct	Long term / intermittent	Low	Minor	Probable	I	Insignificant; Probable
	Habitat modification.	i. Loss/disturbance to spawning habitat.	Direct	Long term/ continuous	Medium	Moderate	Probable	C	Minor; Uncertain
		ii. Loss/ disturbance to foraging habitat.							
	Habitat loss due to dewatering of temporary cofferdam.	i. Gain of spawning habitat	Direct	Long term/ continuous	Positive - Low	Minor	Uncertain	n/a	Minor Positive; Uncertain
		ii. Gain of foraging habitat.							
	Entrainment from draghead	i. Injury and mortality due to dewatering.	Direct	Long term/ intermittent	Neutral	No impact	High	n/a	No impact; High
ii. Reduced fitness									
Operational phase									
Increases in suspended sediment and deposition.	i. Smother spawning grounds.	Direct	Long term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable	
	ii. Impact on larval/ juvenile fish.								
	iii. Behavioural disturbance								

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Valued Ecological Receptor	Impact	Characterisation of impact	Direct/ Indirect	Frequency	Magnitude	Significance without mitigation	Confidence	Mitigation Code (see Table 9.27)	Residual Significance and Confidence Level (adverse unless stated otherwise)
		iv. Injury and mortality.							
	Habitat fragmentation and isolation.	i. Delays to migration. ii. Increased energetic costs. iii. Fragmentation of migratory routes.	Direct	Long term/ continuous	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
	Habitat modification.	i. Loss/disturbance to spawning habitat. ii. Loss/ disturbance to foraging habitat.	Direct	Long term/ continuous	High	Moderate	High	C	Minor; Uncertain
		i. Gain of spawning habitat. ii. Gain of foraging habitat.	Direct	Long term/ continuous	Positive - Medium	Moderate	Uncertain	n/a	Moderate Positive; Uncertain
	Increased predation.	i. Injury and mortality ii. Decreased fitness.	Direct	Long term/ intermittent	Low	Minor	Probable	n/a	Minor; Probable
	Entrainment from draghead	i. Injury and mortality ii. Reduced fitness	Direct	Long term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
	Entrainment and injury from the turbines.	i. Injury and mortality. ii. Decreased fitness	Direct	Long term/ intermittent	High	Moderate	High	F	Moderate; Probable
	Waterborne noise and vibration from turbines.	i. Behavioural disturbance.	Direct	Long term/ intermittent	Negligible	Insignificant	High	n/a	Insignificant; High
	Fluctuations in Lagoon water levels.	i. Behavioural disturbance. ii. Injury and mortality.	Direct	Long term/ intermittent	Neutral	No impact	High	n/a	No impact; High
	Entrainment and injury from sluices.	i. Injury and mortality. ii. Decreased fitness	Direct	Long term/ intermittent	Low	Minor	Probable	n/a	Minor; Probable
	Increases in artificial light emissions.	i. Behavioural disturbance.	Direct	Long term/ continuous	Low	Minor	Probable	I	Insignificant; Probable
	Deterioration in water quality.	i. Behavioural disturbance.	Direct	Long term/ intermittent	Neutral	No impact	High	n/a	No impact; High

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Valued Ecological Receptor	Impact	Characterisation of impact	Direct/ Indirect	Frequency	Magnitude	Significance without mitigation	Confidence	Mitigation Code (see Table 9.27)	Residual Significance and Confidence Level (adverse unless stated otherwise)
		ii. Increased mortality							
	Creation of EMFs.	i. Behavioural avoidance.	Direct	long term/ intermittent	Neutral	No impact	High	n/a	No impact; High
	Waterborne noise and vibration from recreational activities.	i. Behavioural disturbance.	Direct	Long term/ intermittent	Negligible	Insignificant	High	n/a	Insignificant; High
	Increased pressure on fish populations as a result of recreational angling.	i. Increased mortality.	Direct	Long term/ intermittent	Negligible	Insignificant	Uncertain	n/a	Insignificant; Uncertain
Decommissioning Phase									
	Increases in suspended sediment and deposition.	i. Smother spawning grounds. ii. Impact on larval/juvenile fish. iii. Behavioural disturbance. iv. Injury and mortality.	Direct	Short term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
	Increases in underwater noise and vibration.	i. Behavioural disturbance. ii. Injury and mortality.	Direct	Short term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
	Improved connectivity between the habitat within and outside of the Lagoon.	i. Increased access to spawning grounds. ii. Increased access to foraging grounds.	Direct	Long term/ continuous	Positive - Medium	Moderate	Uncertain	n/a	Moderate Positive; Uncertain
	Cumulative								
	Increases in suspended sediment and deposition.	i. Smother spawning grounds. ii. Impact on larval/juvenile fish. iii. Behavioural	Direct	Short term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable



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Valued Ecological Receptor	Impact	Characterisation of impact	Direct/ Indirect	Frequency	Magnitude	Significance without mitigation	Confidence	Mitigation Code (see Table 9.27)	Residual Significance and Confidence Level (adverse unless stated otherwise)
		iv. disturbance. Injury and mortality.							
	Increases in underwater noise and vibration.	i. Behavioural disturbance.	Direct	Short term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
		ii. Injury and mortality.							
	Habitat modification.	i. Loss/disturbance to spawning habitat	Direct	Short term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
		ii. Loss/disturbance to foraging habitat.							
		i. Gain of spawning habitat.	Direct	Short term/ intermittent	Positive - Negligible	Insignificant	Probable	n/a	Insignificant Positive; Probable
		ii. Gain of foraging habitat.							
	Habitat fragmentation and isolation.	i. Delays to migration.	Direct	Long term/ Continuous	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
		ii. Increased energetic costs.							
		iii. Fragmentation of migratory routes.							
	Increased predation.	i. Injury and mortality	Direct	Long term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
	Entrapment by turbines and water abstractions.	ii. Decreased fitness							
		i. Injury and mortality	Direct	Long term/ intermittent	Neutral	No impact	Probable	n/a	No impact; Probable
		ii. Decreased fitness							

Table 9.36 Summary of potential environmental effects on sandeel *Ammodytes* spp.

Valued Ecological Receptor	Impact	Characterisation of impact	Direct/ Indirect	Frequency	Magnitude	Significance without mitigation	Confidence	Mitigation Code (see Table 9.27)	Residual Significance and Confidence Level (adverse unless stated otherwise)
Sandeel <i>Ammodytes</i> spp.	Construction Phase								
	Increases in suspended sediment and deposition.	i. Smother spawning grounds	Direct	Long term/ intermittent	Low	Insignificant	Probable	n/a	Insignificant; Probable
		ii. Impacts on larval/juvenile fish.							
		iii. Behavioural disturbance.							
		iv. Injury and mortality.							
	Increases in underwater noise and vibration.	i. Behavioural disturbance.	Direct	Long term / intermittent	Low	Insignificant	Probable	n/a	Insignificant; Probable
		ii. Injury and mortality.							
	Increase in artificial light emissions.	i. Behavioural disturbance.	Direct	Long term / intermittent	Low	Insignificant	Uncertain	n/a	Insignificant; Uncertain
	Habitat modification.	i. Loss/disturbance to spawning habitat.	Direct	Long term/ continuous	Low	Insignificant	Probable	n/a	Insignificant; Probable
		ii. Loss/ disturbance to foraging habitat.							
	Habitat loss due to dewatering of temporary cofferdam.	i. Gain of spawning habitat	Direct	Long term/ continuous	Positive - Low	Insignificant	Uncertain	n/a	Insignificant Positive; Uncertain
		ii. Gain of foraging habitat.							
	Entrainment from draghead	i. Injury and mortality due to dewatering.	Direct	Long term/ intermittent	Low	Insignificant	Uncertain	n/a	Insignificant; Uncertain
ii. Reduced fitness									
Operational phase									
Increases in suspended sediment and deposition.	i. Smother spawning grounds.	Direct	Long term/ intermittent	Low	Insignificant	Probable	n/a	Insignificant; Probable	
	ii. Impact on larval/juvenile fish.								
	iii. Behavioural								

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Valued Ecological Receptor	Impact	Characterisation of impact	Direct/ Indirect	Frequency	Magnitude	Significance without mitigation	Confidence	Mitigation Code (see Table 9.27)	Residual Significance and Confidence Level (adverse unless stated otherwise)
		disturbance. iv. Injury and mortality.							
	Habitat modification.	i. Loss/disturbance to spawning habitat.	Direct	Long term/ continuous	Medium	Minor	Probable	C	Minor; Probable
		ii. Loss/ disturbance to foraging habitat.							
		i. Gain of spawning habitat.	Direct	Long term/ continuous	Positive - Low	Insignificant	Uncertain	n/a	Insignificant Positive; Uncertain
		ii. Gain of foraging habitat.							
	Increased predation.	i. Injury and mortality	Direct	Long term/ intermittent	Low	Insignificant	Probable	n/a	Insignificant; Probable
		ii. Decreased fitness.							
	Entrainment from draghead	i. Injury and mortality	Direct	Long term/ Intermittent	Low	Insignificant	Probable	n/a	Insignificant; Probable
		ii. Reduced fitness							
	Entrainment and injury from the turbines.	i. Injury and mortality.	Direct	Long term/ intermittent	Negligible	Insignificant	High	n/a	Insignificant; Probable
		ii. Decreased fitness							
	Waterborne noise and vibration from turbines.	i. Behavioural disturbance.	Direct	Long term/ intermittent	Negligible	Insignificant	High	n/a	Insignificant; High
	Fluctuations in Lagoon water levels.	i. Behavioural disturbance.	Direct	Long term/ intermittent	Medium	Minor	Probable	n/a	Minor; Probable
		ii. Injury and mortality.							
	Entrainment and injury from sluices	i. Injury and mortality	Direct	Long term/ Intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
		ii. Reduced fitness							
	Increases in artificial light emissions.	i. Behavioural disturbance.	Direct	Long term/ continuous	Negligible	Insignificant	Probable	n/a	Insignificant; Uncertain
	Deterioration in water quality.	i. Behavioural disturbance.	Direct	Long term/ intermittent	Neutral	No impact	High	n/a	No impact; High
		ii. Increased mortality							
	Creation of EMFs.	i. Behavioural avoidance.	Direct	long term/ intermittent	Neutral	No impact	High	n/a	No impact; High

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Valued Ecological Receptor	Impact	Characterisation of impact	Direct/ Indirect	Frequency	Magnitude	Significance without mitigation	Confidence	Mitigation Code (see Table 9.27)	Residual Significance and Confidence Level (adverse unless stated otherwise)
	Waterborne noise and vibration from recreational activities.	i. Behavioural disturbance.	Direct	Long term/ intermittent	Negligible	Insignificant	High	n/a	Insignificant; High
	Increased pressure on fish populations as a result of recreational angling.	i. Increased mortality.	Direct	Long term/ intermittent	Neutral	No impact	Probable	n/a	No impact; Probable
	Decommissioning Phase								
	Increases in suspended sediment and deposition.	i. Smother spawning grounds. ii. Impact on larval/juvenile fish. iii. Behavioural disturbance. iv. Injury and mortality.	Direct	Short term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
	Increases in underwater noise and vibration.	i. Behavioural disturbance. ii. Injury and mortality.	Direct	Short term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
	Improved connectivity between the habitat within and outside of the Lagoon.	i. Increased access to spawning grounds. ii. Increased access to foraging grounds.	Direct	Long term/ continuous	Positive - Medium	Minor	Uncertain	n/a	Minor; Uncertain
Cumulative									
	Increases in suspended sediment and deposition.	i. Smother spawning grounds. ii. Impact on larval/juvenile fish. iii. Behavioural disturbance. iv. Injury and mortality.	Direct	Short term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable

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Valued Ecological Receptor	Impact	Characterisation of impact	Direct/ Indirect	Frequency	Magnitude	Significance without mitigation	Confidence	Mitigation Code (see Table 9.27)	Residual Significance and Confidence Level (adverse unless stated otherwise)
	Increases in underwater noise and vibration.	i. Behavioural disturbance.	Direct	Short term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
		ii. Injury and mortality.							
	Habitat modification.	i. Loss/disturbance to spawning habitat	Direct	Short term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
		ii. Loss/disturbance to foraging habitat.							
	Increased predation.	i. Gain of spawning habitat.	Direct	Short term/ intermittent	Positive - Negligible	Insignificant	Probable	n/a	Insignificant Positive; Probable
		ii. Gain of foraging habitat.							
	Entrainment by turbines and water abstractions.	i. Injury and mortality	Direct	Long term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
		ii. Reduced fitness							
		i. Injury and mortality	Direct	Long term/ intermittent	Neutral	No impact	Probable	n/a	No impact; Probable
		ii. Decreased fitness							

N.B. Habitat fragmentation and isolation has not been assessed for sandeel as they do not undertake migrations.

Table 9.37 Summary of potential environmental effects on other demersal and pelagic species. Note that receptors are of local to regional value and therefore a magnitude range is given in some cases.

Valued Ecological Receptor	Impact	Characterisation of impact	Direct/indirect	Frequency	Magnitude	Significance without mitigation	Confidence	Mitigation code (see Table 9.27)	Residual significance and confidence level (adverse unless stated otherwise)
Other demersal and pelagic species	Construction phase								
	Increases in suspended sediment and deposition.	i. Smother spawning grounds.	Direct	Long term/intermittent	Negligible to low	Insignificant to Minor.	Probable	A	Insignificant; Uncertain
		ii. Impact on larval/juvenile fish.							
		iii. Behavioural disturbance.							
		iv. Injury and mortality.							
	Increases in underwater noise and vibration.	i. Behavioural disturbance.	Direct	Long term/intermittent	Negligible to low	Insignificant to Minor	High	B	Insignificant; High
		ii. Injury and mortality.							
	Increases in artificial light emissions.	i. Behavioural disturbance.	Direct	Long term/intermittent	Negligible to low	Insignificant to Minor	Uncertain	I	Insignificant; Uncertain
	Habitat modification.	i. Loss/disturbance to spawning habitat.	Direct	Long term/continuous	Negligible to Medium	Insignificant to Moderate	Uncertain	C	Insignificant to Minor; Uncertain
		ii. Loss/disturbance to foraging habitat.							
	Habitat loss due to dewatering of cofferdam.	i. Gain of spawning habitat.	Direct	Long term/continuous	Positive – Negligible to low	Insignificant to Minor	Uncertain	n/a	Insignificant to minor Positive; Uncertain
		ii. Gain of foraging habitat.							
	Entrainment from draghead	i. Injury and mortality during dewatering.	Direct	Long term/intermittent	Negligible to low	Insignificant to Minor	High	D	Insignificant; High
		ii. Reduced fitness.	Direct	Long term/intermittent	Negligible to low	Insignificant to Minor	Uncertain	J	Insignificant to Minor; Uncertain
Operational phase									
	Increases in suspended sediment and deposition.	i. Smother spawning grounds.	Direct	Long term/intermittent	Negligible to Low	Insignificant to Minor	Probable	A	Insignificant to minor; Uncertain
		ii. Impact on larval/juvenile fish.							

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Valued Ecological Receptor	Impact	Characterisation of impact	Direct/indirect	Frequency	Magnitude	Significance without mitigation	Confidence	Mitigation code (see Table 9.27)	Residual significance and confidence level (adverse unless stated otherwise)
		iii. Behavioural disturbance.	Direct	Long term/continuous	Negligible to Low	Insignificant to Minor	Probable	E	Insignificant to minor; Uncertain
		iv. Injury and mortality.							
	Habitat fragmentation and isolation.	i. Delays to migration.	Direct	Long term/continuous	Negligible to Medium	Insignificant to Moderate	Probable	C	Insignificant to Minor; Uncertain
		ii. Increased energetic costs							
		iii. Fragmentation of migratory routes.							
	Habitat modification.	i. Loss/disturbance to spawning habitat.	Direct	Long term/continuous	Positive – Negligible to Medium	Insignificant to Moderate	Probable	n/a	Insignificant to Moderate Positive; Probable
		ii. Loss/disturbance to foraging habitat.							
	Increased predation.	i. Gain of spawning habitat.	Direct	Long term/intermittent	Negligible to low	Insignificant to Minor	Uncertain	n/a	Insignificant to minor; Uncertain
		ii. Increase of foraging habitat.							
	Entrainment from draghead	i. Injury and mortality.	Direct	Long term/intermittent	Negligible to low	Insignificant to Minor	Uncertain	J	Insignificant to Minor; Uncertain
		ii. Reduced fitness.							
	Entrainment and injury from turbines.	i. Injury and mortality.	Direct	Long term/intermittent	Negligible to High	Insignificant to Moderate	Probable	F	Insignificant to Moderate; Uncertain
		ii. Reduced fitness.							
	Waterborne noise and vibration from turbines.	i. Behavioural disturbance.	Direct	Long term/intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
	Fluctuations in Lagoon water levels.	i. Behavioural disturbance.	Direct	Long term/intermittent	Neutral to Negligible	No impact to Insignificant	High	n/a	No impact to insignificant; High
	Entrainment and injury from sluices	ii. Injury and mortality.	Direct	Long term/intermittent	Negligible to low	Insignificant to minor	Probable	n/a	Insignificant to minor; Probable
		i. Injury and mortality.							
	Increases in artificial light emissions.	i. Behavioural disturbance.	Direct	Long term/continuous	Negligible to low	Insignificant to Minor	Probable	I	Insignificant; Probable

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Valued Ecological Receptor	Impact	Characterisation of impact	Direct/indirect	Frequency	Magnitude	Significance without mitigation	Confidence	Mitigation code (see Table 9.27)	Residual significance and confidence level (adverse unless stated otherwise)
	Deterioration in water quality.	i. Behavioural disturbance.	Direct	Long term/intermittent	Neutral to Negligible	No impact to insignificant	High	n/a	No impact to insignificant; High
		ii. Increased mortality.							
	Creation of EMFs.	i. Behavioural avoidance.	Direct	Long term/Intermittent	Neutral	No impact	High	n/a	No impact; High
	Waterborne noise and vibration from recreational activities.	i. Behavioural disturbance.	Direct	Long term/intermittent	Negligible to low	Insignificant to Minor	High	n/a	Insignificant to Minor; High
	Increased pressure on fish populations as a result of recreational angling.	i. Increased mortality.	Direct	Long term/intermittent	Neutral to low	No impact to Minor	Uncertain	n/a	No impact to minor; Uncertain
Decommissioning phase									
	Increases in suspended sediment and deposition.	i. Smother spawning grounds.	Direct	Long term/intermittent	Neutral to Negligible	No impact to Insignificant	Probable	n/a	No impact to Insignificant; Probable
		ii. Impact on larval/juvenile fish and shellfish.							
		iii. Injury and mortality.							
		iv. Behavioural disturbance.							
	Increases in underwater noise and vibration.	i. Behavioural disturbance.	Direct	Long term/intermittent	Neutral to Negligible	No impact to Insignificant	Probable	n/a	No impact to Insignificant; Probable
		ii. Injury and mortality.							
	Improved connectivity between the habitat within and outside of the Lagoon.	i. Increased access to spawning grounds	Direct	Long term/continuous	Positive – Negligible to low	Insignificant to minor	Uncertain	n/a	Insignificant to minor Positive; Uncertain
		ii. Increased access to foraging grounds.							

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Valued Ecological Receptor	Impact	Characterisation of impact	Direct/indirect	Frequency	Magnitude	Significance without mitigation	Confidence	Mitigation code (see Table 9.27)	Residual significance and confidence level (adverse unless stated otherwise)
	Cumulative impacts								
	Increases in suspended sediment and deposition.	i. Smother spawning grounds. ii. Impact on larval/juvenile fish and shellfish. iii. Injury and mortality. iv. Behavioural disturbance.	Direct	Long term/intermittent	Neutral to Negligible	No impact to Insignificant	Probable	n/a	No impact to Insignificant; Probable
		i. Behavioural avoidance. ii. Injury and mortality.	Direct	Long term/intermittent	Neutral to Negligible	No impact to Insignificant	Probable	n/a	No impact to Insignificant; Probable
		i. Loss/disturbance to spawning habitat. ii. Loss/disturbance to foraging habitat.	Direct	Long term/intermittent	Neutral to Negligible	No impact to Insignificant	Probable	n/a	No impact to Insignificant; Probable
		i. Gain of spawning habitat. ii. Gain of foraging habitat.	Direct	Long term/intermittent	Positive – Negligible to low	Insignificant to minor	Uncertain	n/a	Insignificant to minor positive; Uncertain
	Habitat fragmentation and isolation.	i. Delays to migration. ii. Increased energetic costs iii. Fragmentation of migratory routes.	Direct	Long term/continuous	Neutral to Negligible	No impact to Insignificant	Probable	n/a	No impact to Insignificant; Probable
		i. Injury and mortality. ii. Reduced fitness.	Direct	Long term/intermittent	Neutral to Negligible	No impact to Insignificant	Probable	n/a	No impact to Insignificant; Probable
	Entrainment by turbines and water abstractions.	i. Injury and mortality. ii. Decreased fitness.	Direct	Long term/intermittent	Neutral to Negligible	No impact to Insignificant	Probable	n/a	No impact to Insignificant; Probable

Table 9.38 Summary of potential environmental effects on commercial shellfish

Valued Ecological Receptor	Impact	Characterisation of impact	Direct/ Indirect	Frequency	Magnitude	Significance without mitigation	Confidence	Mitigation Code (see Table 9.27)	Residual Significance and Confidence Level (adverse unless stated otherwise)
Commercial Shellfish	Construction Phase								
	Increases in suspended sediment and deposition.	i. Smother spawning grounds	Direct	Long term/ intermittent	Negligible	insignificant	Probable	n/a	Insignificant; Probable
		ii. Impacts on larval/juvenile fish.							
		iii. Behavioural disturbance.							
		iv. Injury and mortality.							
	Increases in underwater noise and vibration.	i. Behavioural disturbance	Direct	Long term/ intermittent	Neutral	No impact	Uncertain	n/a	No impact; Uncertain
		ii. Injury and mortality							
	Increases in artificial light emissions.	i. Behavioural disturbance	Direct	Long term/ intermittent	Neutral	No impact	Uncertain	n/a	No impact; Uncertain
	Habitat modification.	ii. Loss/disturbance to spawning habitat.	Direct	Long term/ continuous	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
		iii. Loss/ disturbance to foraging habitat.							
		i. Gain of spawning habitat							
	Habitat loss due to dewatering of temporary cofferdam.	ii. Gain of foraging habitat.	Direct	Long term/ intermittent	Positive - Medium	Moderate	Probable	n/a	Moderate Positive; Probable
		i. Injury and mortality due to dewatering.							
		ii. Injury and mortality							
	Entrainment from draghead	ii. Reduced fitness	Direct	Long term/ intermittent	Low	Minor	Uncertain	J	Minor; Uncertain
Operational phase									
	Increases in suspended sediment and deposition.	i. Smother spawning grounds.	Direct	Long term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
		ii. Impact on larval/juvenile fish.							
		iii. Behavioural disturbance.							

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Valued Ecological Receptor	Impact	Characterisation of impact	Direct/ Indirect	Frequency	Magnitude	Significance without mitigation	Confidence	Mitigation Code (see Table 9.27)	Residual Significance and Confidence Level (adverse unless stated otherwise)
		iv. Injury and mortality.							
	Habitat fragmentation and isolation	i. Fragmentation of habitat	Direct	Long term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
	Habitat modification.	i. Loss/disturbance to spawning habitat. ii. Loss/ disturbance to foraging habitat.	Direct	Long term/ continuous	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
		i. Gain of spawning habitat. ii. Gain of foraging habitat.	Direct	Long term/ continuous	Positive - Medium	Moderate	Probable	n/a	Moderate Positive; Probable
	Increased predation	i. Injury and mortality ii. Reduced fitness	Direct	Long term/ continuous	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
	Entrainment from draghead	i. Injury and mortality ii. Reduced fitness	Direct	Long term/ intermittent	Low	Minor	Uncertain	J	Minor; Uncertain
	Entrainment and injury from turbines.	i. Injury and mortality. ii. Reduced fitness.	Direct	Long term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
	Waterborne noise and vibration from turbines.	i. Behavioural disturbance.	Direct	Long term/ intermittent	Neutral	No impact	Uncertain	n/a	No impact; Uncertain
	Fluctuations in Lagoon water levels.	i. Behavioural disturbance. ii. Injury and mortality.	Direct	Long term/ intermittent	Low	Minor	Uncertain	n/a	Minor; Uncertain
	Entrainment and injury from sluices	i. Injury and mortality. ii. Reduced fitness.	Direct	Long term/ intermittent	Negligible	Insignificant	Uncertain	n/a	Insignificant; Uncertain
	Increases in artificial light emissions.	i. Behavioural disturbance	Direct	Long term/ intermittent	Neutral	No impact	Uncertain	n/a	No impact; Uncertain
	Deterioration in water quality.	i. Behavioural disturbance. ii. Increased mortality	Direct	Long term/ intermittent	Negligible	Insignificant	High	n/a	Insignificant; High
	Creation of EMFs	i. Behavioural disturbance	Direct	Long term/ continuous	Neutral	No impact	Probable	n/a	No impact; Probable

Tidal Lagoon Swansea Bay plc

Valued Ecological Receptor	Impact	Characterisation of impact	Direct/ Indirect	Frequency	Magnitude	Significance without mitigation	Confidence	Mitigation Code (see Table 9.27)	Residual Significance and Confidence Level (adverse unless stated otherwise)
	Waterborne noise and vibration from recreational activities.	i. Behavioural disturbance.	Direct	Long term/ intermittent	Neutral	No impact	High	n/a	No impact; High
	Increased pressure on commercial shellfish populations as a result of recreational angling.	i. Increased mortality.	Direct	Long term/ intermittent	Neutral	No impact	High	n/a	No impact; High
	Decommissioning Phase								
	Increases in suspended sediment and deposition.	i. Smother spawning grounds. ii. Impact on larval/juvenile fish. iii. Behavioural disturbance. iv. Injury and mortality.	Direct	Short term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
	Increases in underwater noise and vibration.	i. Behavioural disturbance ii. Injury and mortality	Direct	Long term/ intermittent	Neutral	No impact	Uncertain	n/a	No impact; Uncertain
	Improved connectivity between the habitat within and outside of the Lagoon.	i. Increased access to spawning grounds ii. Increased access to foraging grounds.	Direct	Long term/ continuous	Positive - Negligible	Insignificant	Probable	n/a	Insignificant Positive; Probable
	Cumulative								
	Increases in suspended sediment and deposition.	i. Smother spawning grounds. ii. Impact on larval/juvenile fish. iii. Behavioural	Direct	Short term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable

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Valued Ecological Receptor	Impact	Characterisation of impact	Direct/ Indirect	Frequency	Magnitude	Significance without mitigation	Confidence	Mitigation Code (see Table 9.27)	Residual Significance and Confidence Level (adverse unless stated otherwise)
		iv. disturbance. Injury and mortality.							
	Increases in underwater noise and vibration.	i. Behavioural disturbance.	Direct	Short term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
		ii. Injury and mortality.							
	Habitat modification.	i. Loss/disturbance to spawning habitat	Direct	Short term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
		ii. Loss/disturbance to foraging habitat.							
		i. Gain of spawning habitat.	Direct	Short term/ intermittent	Positive - Negligible	Insignificant	Probable	n/a	Insignificant; Probable
		ii. Gain of foraging habitat.							
	Habitat fragmentation and isolation	i. Fragmentation of habitat	Direct	Long term/ intermittent	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
	Increased predation	i. Injury and mortality	Direct	Long term/ continuous	Negligible	Insignificant	Probable	n/a	Insignificant; Probable
		ii. Reduced fitness							
	Entrapment by turbines and water abstractions	i. Injury and mortality	Direct	Long term/ intermittent	Neutral	No impact	High	n/a	No impact; High
		ii. Decreased fitness							

N.B. Certain impact characterisations have been removed/modified for commercial shellfish.

9.5.8 Water Framework Directive

- 9.5.8.1 The Water Framework Directive (2000/60/EC) is a European Instrument which seeks to improve and integrate the way water bodies are managed across Europe by 'establishing a framework for the community action in the field of water policy'. The fundamental principle of the Directive is to protect water resources and to promote sustainable water use. The Directive is transposed into law in England and Wales by the Water Environment (Water Framework Directive) (England and Wales) Regulations 2003. The objectives of the directive are summarised in Table 9.39.

Table 9.39 Summary of Water Framework Directive objectives

Objectives	Reference
Member states shall implement the necessary measures to prevent deterioration of the status of all bodies of surface water.	4.1(a)(i)
Member states shall protect, enhance, and restore all bodies of surface water, subject to the application of subparagraph (iii) for artificial and heavily modified bodies of water, with the aim of achieving good surface water status by 2015.	4.1(a)(ii)
Member states shall protect and enhance all artificial and heavily modified water bodies of water, with the aim of achieving good ecological potential and good surface water chemical status by 2015	4.1(a)(iii)
Progressively reduce pollution from priority substances and cease or phasing out emissions, discharges and losses of priority hazardous substances.	4.1(a)(iv)

- 9.5.8.2 The WFD creates a mechanism through which each signatory has to aim to bring its water resources to an accepted biological and chemical standard (good ecological/chemical status for natural water bodies; and good ecological potential/good chemical status for artificial/heavily modified water bodies) by 2015; this is based on a series of parameters (quality elements) dependent on the type of water body considered (i.e. rivers; lakes; transitional waters and coastal waters) and its hydromorphological designation (i.e. natural; artificial or heavily modified). In cases where good status/potential cannot be achieved by 2015 a provision is given under Article 4.4 of the directive allowing extending the deadline to 2021 or 2027. Within England and Wales the competent authority, as of 2013, for delivering the Directive is NRW (preceded by the Environment Agency).
- 9.5.8.3 Water Framework Directive quality elements include biological, hydromorphological, physio-chemical parameters.
- 9.5.8.4 The Directive states that 'the ecological status classification for the body of water shall be represented by the lower of the values for the biological and physico-chemical monitoring results for the relevant quality element'. Results are judged against a five point scale: High; Good; Moderate; Poor; and Bad. Thus, for instance, if a water body achieved a high status for all of its biological quality elements (including fish fauna) with exception of phytoplankton, which achieved a poor, the overall ecological status will be judged as poor.
- 9.5.8.5 The quality element "fish fauna", within river waterbodies, is assessed against criteria drafted by the United Kingdom Technical Advisory Group on Water Framework Directive (UKTAG) (WFD-UKTAG, 2008). A set of 23 indicator species, with differing tolerances to environmental disturbance are used to classify rivers according to the monitoring requirements of the WFD. However, within the waterbodies concerned, only populations of eel, stone loach *Barbatula barbatula*, bullhead *Cottus gobio*,



lamprey *Lampetra fluviatilis*, salmon and trout are monitored. It should be noted that although sea lamprey *Petromyzon marinus* have been known sporadically enter some of the rivers in Swansea Bay, no known populations exist, thus they are not considered to contribute significantly to the WFD fish fauna quality element. Data used to quantify the fish fauna WFD quality element is taken from seasonal fish surveys undertaken in each waterbody. For salmon and trout only juveniles contribute to WFD calculations, adults are excluded from them.

- 9.5.8.6 For transitional waters, the “fish” quality element is determined using the UKTAG Transitional Fish Classification Index (TFCI); a multi-metric assessment which compares the observed parameters (e.g. abundance and diversity of a fish population) of a waterbody with a reference condition for that ecotype.
- 9.5.8.7 Any activity which has the potential to have an impact on ecology needs consideration in terms of whether it can cause deterioration to the ecological status or potential of a waterbody. It is necessary therefore to consider the possible changes associated to these against the impacts of the Project.
- 9.5.8.8 The only species, which could be affected by the Project, and contribute significantly to the WFD status of river waterbodies within Swansea Bay are diadromous fish, namely salmon, eel and lamprey. Sea trout, although contributing, are recognised as playing a smaller role, owing to the fact that both freshwater resident and anadromous fish are counted cumulatively, and the relative population size of resident fish is significantly larger.

The Project and its relationship with WFD waterbodies

- 9.5.8.9 The Lagoon will be located within Swansea Bay (WFD waterbody ID and name: GB641008260000 Swansea Bay) which is designated as a coastal water under the Water Framework Directive and linked to waterbodies identified in Table 9.40. Swansea Bay itself is a coastal waterbody, designated as Heavily Modified, and as such its fish population is not one of the ecological quality elements used in its WFD assessment, as a result it will not be discussed further in this assessment. However, given that the Afan, Kenfig, Neath and Tawe all have migratory fish populations, are designated as freshwaters, and are connected to Swansea Bay, an assessment of the scheme on their WFD in relation to fish must be made. Additionally, impacts on the three transitional waterbodies must be quantified.
- 9.5.8.10 Within this section only impacts relating to the fish quality elements of the waterbodies in question are discussed, for an overall assessment please refer to Water Framework Directive Assessment (TLSB, 2014). As a result remaining quality elements have not been considered further in this assessment.

WFD baseline

- 9.5.8.11 Swansea Bay lies within the Western Wales River Basin Management Plan (RBMP) area. All coastal, estuarine and river waterbodies were identified from the RBMP; in addition, to ensure the most up to date information was included, data relating to WFD statuses was also sourced directly from NRW.
- 9.5.8.12 There are a total of 50 WFD waterbodies associated with Swansea Bay: the majority of which (46) are classed as river waterbodies, with three transitional waterbodies and a single coastal water body.

- 9.5.8.13 The four principal rivers flowing into Swansea Bay are the Tawe, Afan, Neath and Kenfig (Figure 9.33). For the purposes of WFD classification these rivers are split further into management units, each river has several of these: Tawe=16; Afan=6; Neath=17; and, Kenfig=5. An additional two freshwater water bodies not connected to the above catchments flow within Swansea Bay, the Clyne River, and the Brynmill Stream. The three transitional water bodies are associated to the estuaries of the principal rivers, whilst the single coastal waterbody represents the whole of Swansea Bay (Table 9.40).

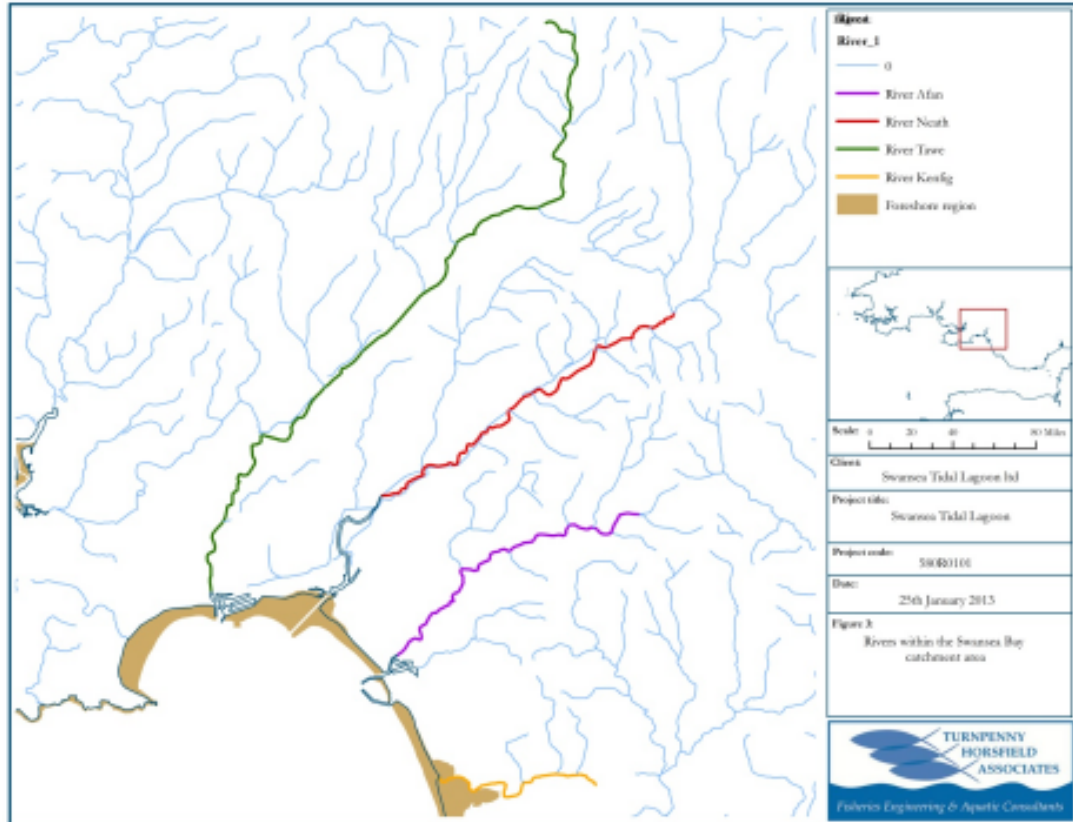


Figure 9.33 Principal river systems flowing into Swansea Bay.

- 9.5.8.14 Each management unit is given an overall 'class' which represents its overall WFD status/potential. Currently, out of the 46 river waterbodies within the Swansea Bay region, 17 are judged as having good overall class; 21 as moderate; 4 as poor and 4 have not yet been assessed. All transitional waterbodies are judged as currently achieving a good overall class, whilst Swansea Bay is currently achieving an overall bad class (Table 9.40; Figure 9.34).

Table 9.40 WFD Waterbodies linked to Swansea Bay

Catchment	Waterbody ID	Current Ecological Status/ Potential	Fish quality element status	Failing elements which have been assessed	Elements not assessed (2012)	Overall risk category	Risks	Ecological Objective
Rivers								
Afan	GB110058026100	Moderate	Moderate	Fish	Morphology; Hydrology	At risk	A;B	Good ecological status by 2027
	GB110058026110	Moderate	No fish data	Mitigation measures assessment	Fish; diatoms; macrophytes	At risk	C	Good ecological potential by 2027
	GB110058026120	Good	Good	None	Macrophytes; diatoms and morphology	At risk	A	Good ecological status by 2015
	GB110058026130	Good	Good	None	Morphology; hydrology	At risk	A;D;C	Good ecological status by 2027
	GB110058026140	Poor	Poor	Invertebrates; fish	Macrophytes; diatoms; morphology	At risk	A;B;D;E;F	Good ecological status by 2027
	GB110058026150	Good	Good	None	Macrophytes; diatoms; phosphate; temperature; diss. oxygen; pH; ammonia; morphology; hydrology	At risk	A;B;D;M;N;C	Good ecological status by 2027
Kenfig	GB110058026160	Good	No fish data	None	Macrophytes; diatoms; invertebrates; fish; morphology; hydrology	Probably at risk	A;G;H;C	Good ecological status by 2027
	GB110058026170	Good	Good	None	Macrophytes; diatoms; morphology; hydrology	At risk	A;B	Good ecological status by 2015
	GB110058026180	NYA	No fish data	None	Macrophytes; diatoms; invertebrates; fish; phosphate; temperature; diss. oxygen; pH; ammonia; morphology; hydrology	Probably at risk	A;G;H;C	Good ecological status by 2015
	GB110058026190	Moderate	Moderate	Fish	Macrophytes; diatoms; invertebrates; morphology; hydrology	At risk	A;B;H	Good ecological status by 2027
	GB110058026450	Moderate	No fish data	Diatoms	Fish; morphology; hydrology	Probably at risk	H	Good ecological status by 2027
	GB110058026350	NYA	No fish data	None	Macrophytes; diatoms; invertebrates; fish; phosphate; temperature; diss. oxygen; pH; ammonia; morphology	Probably at risk	A;G	Good ecological status by 2015
Neath	GB110058026360	Moderate	No fish data	None	Macrophytes; diatoms; invertebrates; fish; phosphate; temperature; diss. oxygen; pH; ammonia; morphology	Probably at risk	A;G	Good ecological status by 2027



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GB110058026370	Moderate	No fish data	Mitigation measures assessment	Macrophytes; diatoms; invertebrates; fish; phosphate; temperature; diss. oxygen; pH; ammonia; morphology	At risk	C;A;G	Good ecological potential by 2027
GB110058026380	Poor	Poor	Fish	Macrophytes; diatoms; invertebrates; phosphate; temperature; diss. oxygen; pH; ammonia; morphology	At risk	A;B	Good ecological status by 2015
GB110058026390	Moderate	Moderate	Fish	Macrophytes; diatoms; morphology	At risk	A;B;K	Good ecological status by 2027
GB110058032320	Good	Good	None	Macrophytes; diatoms; morphology; hydrology	At risk	O;J;A;B;K;M;P;C	Good ecological status by 2027
GB110058032330	NYA	No fish data	None	Macrophytes; diatoms; invertebrates; fish; phosphate; temperature; diss. oxygen; pH; ammonia; morphology; hydrology	Probably not at risk		Good ecological status by 2015
GB110058032340	Good	No fish data	None	Macrophytes; diatoms; fish; morphology	Probably not at risk		Good ecological status by 2015
GB110058032350	Good	No fish data	None	Macrophytes; diatoms; invertebrates; fish; morphology; hydrology	Probably not at risk		Good ecological status by 2015
GB110058032360	Poor	Poor	Fish	Macrophytes; diatoms; morphology; hydrology	At risk	O;L;M;N;P;E;F;A;B	Good ecological status by 2027
GB110058032370	Moderate	Moderate	Fish	Macrophytes; diatoms; invertebrates; morphology	At risk	A;I	Good ecological status by 2015
GB110058032380	Moderate	Good	Annex 8 (pollutants)	Macrophytes; diatoms; morphology; hydrology	Probably at risk	A;Q;I	Good ecological status by 2015
GB110058032390	Moderate	Moderate	Fish; Annex 8 (pollutants)	Macrophytes; diatoms; morphology	Probably not at risk		Good ecological status by 2027
GB110058032400	Good	Good	None	Macrophytes; diatoms; invertebrates; morphology	At risk	A;I	Good ecological status by 2027
GB110058032410	Moderate	Moderate	Fish	Macrophytes; diatoms; invertebrates; morphology	Probably not at risk		Good ecological status by 2015



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Tawe	GB110058032420	Good	Good	None	Macrophytes; diatoms; invertebrates; morphology; hydrology	At risk	A;C	Good ecological status by 2015
	GB110058032430	Moderate	Good	Diatoms; Annex 10 (pollutants)	Morphology; hydrology	At risk	A;B;D;C;O;J	Good ecological status by 2015
	GB110059025690	Moderate	No fish data	Mitigation measures	Macrophytes; diatoms; invertebrates; fish; phosphate; temperature; diss. oxygen; pH; ammonia; morphology	At risk	C;A;G;K	Good ecological potential by 2027
	GB110059025700	Moderate	No fish data	None	Macrophytes; diatoms; invertebrates; fish; phosphate; temperature; diss. oxygen; pH; ammonia; morphology; hydrology	Probably at risk	A;G	Good ecological status by 2027
	GB110059025710	Moderate	Good	Diss. Oxygen; Annex 10 (pollutants); Mitigation measures	Morphology	At risk	C;A;K	Good ecological potential by 2027
	GB110059032170	Good	High	None	Macrophytes; diatoms; morphology; hydrology	At risk	O;L	Good ecological status by 2027
	GB110059032180	Moderate	High	Diatoms	Morphology	At risk	O;L	Good ecological status by 2015
	GB110059032190	Good	High	None	Diatoms; morphology	Probably at risk	A;D	Good ecological status by 2015
	GB110059032200	Moderate	High	Invertebrates	Macrophytes; diatoms; morphology	Probably at risk	A;B	Good ecological status by 2015
	GB110059032210	Moderate	No fish data	Invertebrates; Annex 8 (pollutants); Mitigation measures	Diatoms; fish; morphology	At risk	C;A;D	Good ecological potential by 2015
	GB110059032220	Moderate	Good	Mitigation measures	Macrophytes; diatoms; invertebrates; morphology	At risk	C;A;D	Good ecological potential by 2027
	GB110059032240	Good	Good	None	Diatoms; phosphate; temperature; diss. oxygen; pH; ammonia; morphology; hydrology	Probably not at risk		Good ecological status by 2015
	GB110059032250	Good	Good	None	Macrophytes; diatoms; invertebrates; phosphate; temperature; diss. oxygen; pH; ammonia; morphology	At risk	A;D	Good ecological status by 2015

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	GB110059032260	Good	Good	None	Macrophytes; morphology	At risk	A;D;E; F;C	Good ecological status by 2027
	GB110059032270	Good	No fish data	None	Macrophytes; diatoms; fish; morphology	Probably at risk	M;N	Good ecological status by 2015
	GB110059032280	Moderate	Good	None	Macrophytes; diatoms; morphology	At risk	O;J;A; D;E;F	Good ecological status by 2027
	GB110059032290	NYA	No fish data	None	Macrophytes; diatoms; invertebrates; fish; phosphate; temperature; diss. oxygen; pH; ammonia; morphology			Good ecological status by 2015
	GB110059032300	Good	Good	None	Diatoms; invertebrates; morphology; hydrology	Probably at risk	A;I	Good ecological status by 2015
Brynmill Stream	GB110059025600	Moderate	No fish data	Mitigation measures	Macrophytes; diatoms; invertebrates; fish; phosphate; temperature; diss. oxygen; pH; ammonia; morphology	No data	No data	Good ecological potential by 2027
Clyne River	GB110059025620	Poor	Poor	Fish; ammonia	Diatoms	No data	No data	Good ecological status by 2027
Transitional waters								
Tawe	GB541005900900	Good	No fish data	None	Phytoplankton; macrophytes; invertebrates; temperature; diss. oxygen; salinity; nutrient status; other pollutants; priority substances	No data	No data	Good ecological potential by 2015
Neath	GB541005800700	Good	No fish data	None	Phytoplankton; macrophytes; invertebrates; temperature; salinity; nutrient status; other pollutants	No data	No data	Good ecological potential by 2015
Afan	GB541005800600	Good	No fish data	None	Phytoplankton; macrophytes; invertebrates; temperature; diss. oxygen; salinity; nutrient status; other pollutants; priority substances	No data	No data	Good ecological potential by 2015
Coastal waters								
Swansea Bay		Bad	n/a	Phytoplankton; Dissolved inorganic nitrogen; Mitigation measures.	Macrophytes; Invertebrates; morphology; temperature; nutrient status	No data	No data	Good ecological potential by 2027

Risks: A= Diffuse source pollution; B=Mines and minewaters; C=Dangerous substances; K=Urbanisation; L=Metals; M=Combined source sanitary; N=Ammonia; O=Point source pollution; P=Biological oxygen demand; Q=Pesticides. N abstraction and flow regulation; I=Sheep dip; J=Dangerous substances; K=Urbanisation; L=Metals; M=Combined source sanitary; N=Ammonia; O=Point source pollution; P=Biological oxygen demand; Q=Pesticides. N

*Note: risks are presented in two colours: red for actively at risk from; and blue for probably at risk from. Data for transitional, coastal waters, the Clyne river and the Brynmill Stream was not part of the 2012 dataset used for rivers but was extracted from the Environment Agency River Basin Management Plan (2009).

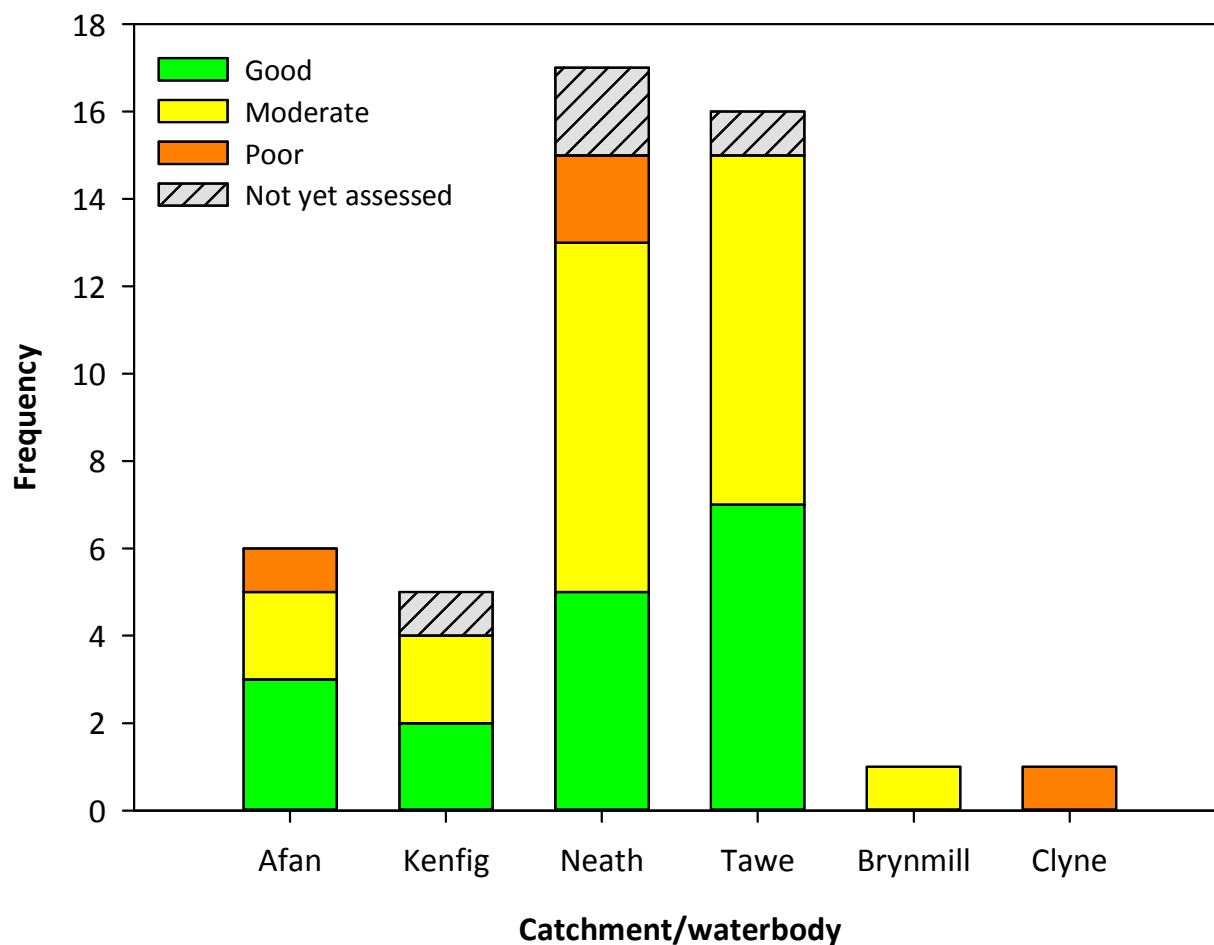


Figure 9.34 Overall status/potential for rivers flowing into Swansea Bay. The Tawe, Neath and Afan transitional waterbodies have been excluded from the above graph.

- 9.5.8.15 Each river unit is also given a fish quality element status, which are summarised in Figure 9.35. As can be seen, the fish population of several waterbodies has not been quantified in terms of fish population. This is most likely owing to the fact that monitoring for WFD purposed is risk based, and some sites are prioritised over others. In certain cases, where site specific surveys are lacking, a precautionary value of '*moderate*' is given to the fish quality element of a waterbody. Additionally, over time, waterbodies may have been consolidated or split for management purposes.

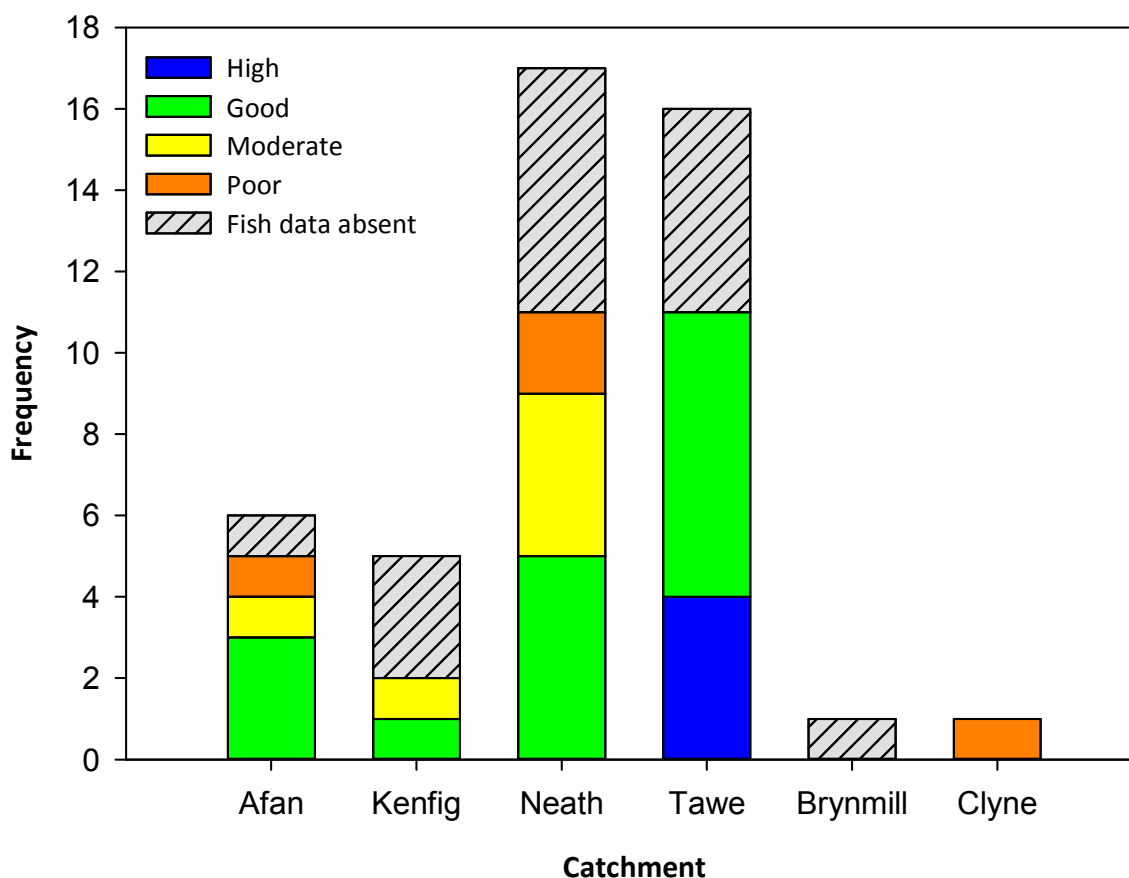


Figure 9.35 Overall status for fish ecological quality element for rivers flowing into Swansea Bay

Pressures on WFD fishery quality element

- 9.5.8.16 As well as providing statuses for all quality elements, WFD management plans provide evidence regarding the potential risks associated to waterbodies (Table 9.40). Figure 9.36 summarises the potential risks that have been identified for waterbodies flowing within Swansea Bay. As is evident, the biggest risk to waterbodies within the Swansea Bay region is diffuse source pollution, most likely from farming effluent (Environment Agency, n.d.). Physical/morphological alteration to rivers also poses a significant risk to waterbodies, this includes barriers such as weirs. The Tawe Salmon Action Plan (Environment Agency, 2002b) estimates that of the 95.9 km of river length within the catchment only 46 km (47 %) are accessible to migratory fish, though it must be noted that the report was produced in 2001 and no data is available as to the current availability of habitat.

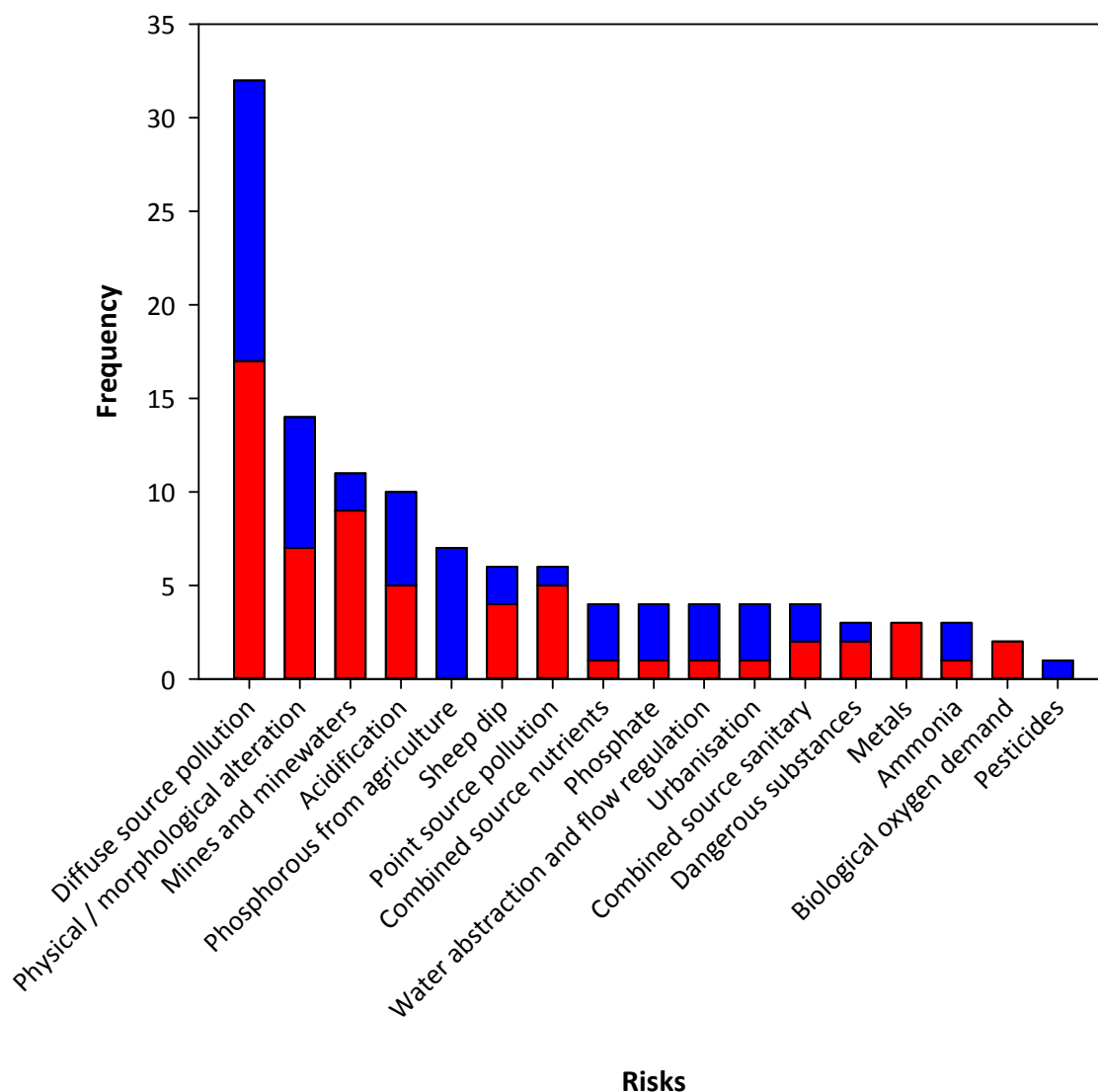


Figure 9.36 Risks to waterbodies linked to Swansea Bay. Blue shading indicates potential risk, whilst red indicates actively at risk.

- 9.5.8.17 Fishing pressure on anadromous fish can also contribute to stress on the WFD fish fauna quality element by removing spawning stock from waterbodies. Typically, recreational angling of salmon and sea trout targets “fresh run” fish which have yet to spawn, ultimately contributing to decreasing the number of juveniles which have the potential to be caught during seasonal surveys. Eel and lamprey are not typically directly targeted.
- 9.5.8.18 Environment Agency (now NRW) data, based on declared catches, provides a record of fish which have been taken from the waterbodies in question. Figure 9.36 summarises the percentage of salmon lost as a result of recreational angling for the period between 2002 and 2011 in the R. Afan, Neath and Tawe. The greatest losses have occurred on the Tawe (range=54.3 % - 86.88 %), followed by the Neath (range= 39.62 % – 77.92 %) and Afan (range= 0 - 80 %).

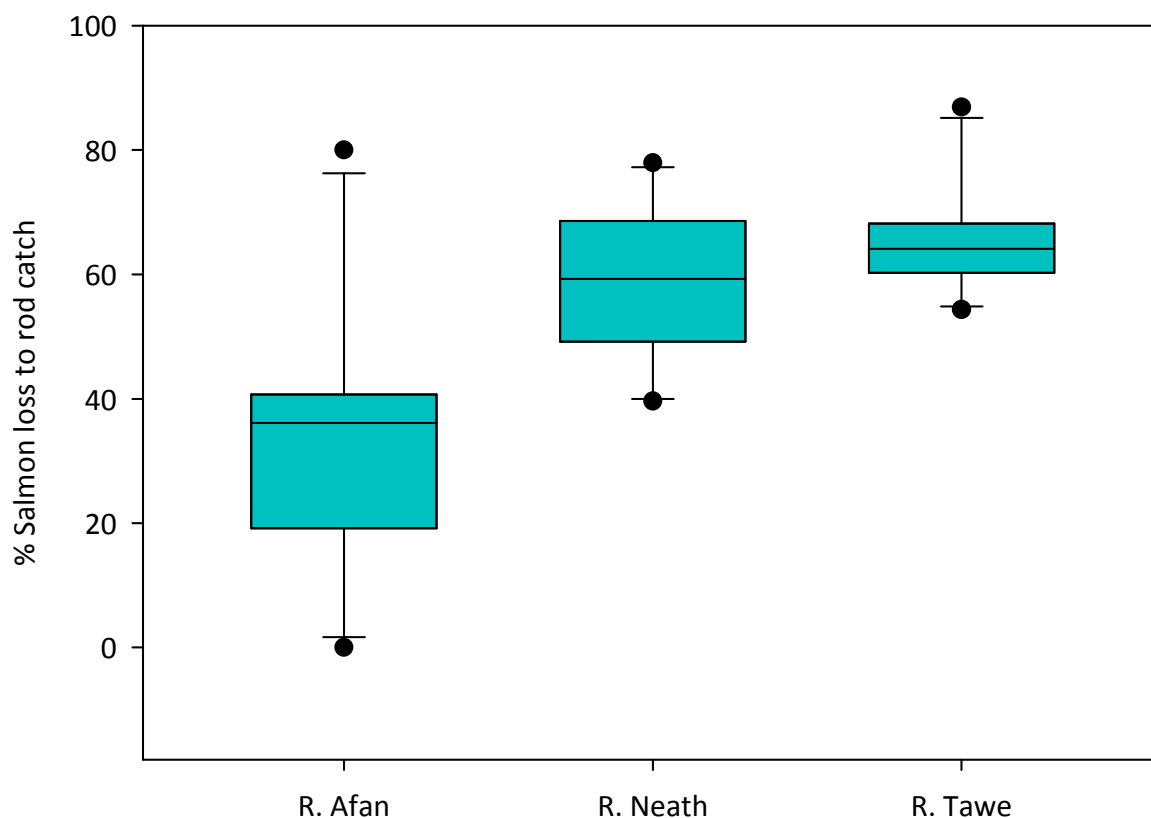


Figure 9.37 Salmon losses to recreational fishing between 2002 and 2011.

9.5.8.19 The inter-yearly variation in the number of fish kept is significant (Table 9.41), as is the number of fish caught. The numbers presented are not representative of the total population of the rivers in question, and care must be taken to interpret the data, as the relationship between catch and stock size is complex.

Table 9.41 Reported salmon catches between 2002 and 2011 on the R. Afan, Neath and Tawe (Environment Agency, 2002a; 2003;2004; 2005; 2006; 2007; 2008; 2009b; 2010b; 2011b)

Year	River					
	Afan		Neath		Tawe	
	Reported	Returned	Reported	Returned	Reported	Returned
2002	7	4	90	44	148	56
2003	5	4	35	15	61	8
2004	10	6	73	21	155	50
2005	6	5	37	14	164	50
2006	5	3	85	48	184	72
2007	3	3	53	32	183	74
2008	9	6	99	32	195	63
2009	15	10	62	26	114	45
2010	18	11	76	30	230	105
2011	10	2	77	17	109	37



WFD assessment

- 9.5.8.20 A number of impacts which have the potential to affect migratory fish have been fully assessed earlier in this Chapter. A summary of these is provided below:
- i. Underwater noise – from the piling operations, dredging and general construction activity during the construction phase of the project
 - ii. Fragmentation of migratory routes – from the insertion of a new seawall (the Lagoon wall) within Swansea Bay
 - iii. Entrainment and injury in turbines – from operation of the tidal turbines
 - iv. Entrainment and injury in sluices – from operation of the tidal lagoon
 - v. Increases in suspended sediment – from construction works
 - vi. Increases in artificial light – from lights used during construction and operation
 - vii. Habitat modification – from various construction works
 - viii. Increased mortality – from increases in recreational angling as a result of the development
 - ix. Creation of Electro Magnetic Fields – from electric cabling used in the Project
- 9.5.8.21 Conclusions drawn indicate that the likely effect of the above impacts on the populations of salmon, eel and lamprey within Swansea Bay will be minimal.
- 9.5.8.22 Anadromous fish populations experience significant natural inter-annual variation, dominated by super-regional influences (Harris & Milner, 2004; Tesch, 2003). Marine mortality is often significant, and is thought to represent an important determinant of low adult return rates (Aas et al., 2011). As described above, the population of anadromous fish within the River Tawe is prone to natural fluctuation, this is reflected in the number of fish declared by rod fishermen during yearly catch return data (Environment Agency, n.d.); numbers of anadromous fish returning to the R. Neath and Afan also fluctuate yearly.
- 9.5.8.23 In light of the above, and assessments made, the pressures exerted from the Project on anadromous fish populations are by far outweighed by the natural dynamics (e.g. predation at sea) which influence stock recruitment. Additionally, risks posed from in-river sources, are likely to have a much greater impact than the Project itself.
- 9.5.8.24 It is therefore concluded, that the Project, and associated impacts, are unlikely to cause deterioration in the fish fauna quality element for the waterbodies identified, and ultimately, the effects are unlikely to prevent the current WFD status objectives from being achieved.

9.6 Commercial fisheries

9.6.1 Commercial fisheries baseline characterisation

- 9.6.1.1 Baseline characterisation of commercial and recreational fisheries data was gathered primarily through consultation with local fisheries representatives and individual fishermen. Official statistics for commercial fisheries were sourced from the Marine Management Organisation (MMO) for the period 2006 to 2012 for the ICES rectangles in which the Project will be located (32E6), and for surrounding areas (32E5 and 31E6).



9.6.1.2 For commercial fisheries, evidence indicated that the ICES rectangle (see Appendix 9.1, Volume 3) in which the Project will be located was of low importance when compared to the wider area, with total landings over the seven year period representing < 1 % of the total value for the three adjacent rectangles.

9.6.1.3 A comparison of landings from the statistical rectangles encompassing and surrounding the Project and wider UK landings from 2008 to 2012 is given in Table 9.42. Whilst Table 9.43 gives a summary of those same national landings in relation to the landings from rectangle 32E6, the same area as the Project.

Table 9.42 Comparison of landings from ICES rectangles within the Swansea Bay region and wider UK fisheries (2008 – 2012)

Ten most commercially caught species in the area surrounding and encompassing the Project in 2012 (32E5, 32E6 and 31E6)		UK wide landings for the species	Landings from Project area compared to wider UK landings (%)
Species	Tonnes caught (t)	Tonnes caught (t)	
Whelks	4854.8	71300	6.8
Cockles	1827.5	23400	7.8
Mussels	559.5	13700	4.1
Crabs	405.1	134500	0.3
Raja spp.	313.1	13400	2.3
Bass	206.7	3700	5.6
Scallops	39.1	210500	1.9×10^{-2}
Mullet spp.	37.8	-	-
Common sole	35.0	9200	0.4
Plaice	30.8	15200	0.2

Table 9.43 Comparison of landings from rectangle 32E6 and wider UK fisheries (2008 - 2012)

Ten most commercially caught species in the statistical rectangle in which the Project is situated (32E6)		UK wide landings for the species	Landings from rectangle 32E6 compared to wider UK landings (%)
Species	Tonnes caught (t)	Tonnes caught (t)	
Whelks.	11.9	71300	1.7×10^{-2}
Raja spp.	2.5	13400	1.9×10^{-2}
Lobsters	0.9	14500	6.2×10^{-3}
Bass	0.8	3700	2.2×10^{-2}
Smooth hound	0.4	-	-
Mullet spp.	0.3	-	-
Common sole	0.2	9200	2.2×10^{-3}
Cod	0.1	51500	1.9×10^{-4}
Flounder	0.1	-	-
Plaice	0.1	15200	6.6×10^{-4}

9.6.1.4 Over the five year period from 2008 to 2012 Whelks represented the most prevalent catch in terms of tonnes of fish and shellfish caught from the 3 ICES statistical rectangles in the wider zone of the Project. The 4854.8 tonnes of fish represented 6.8 % of whelks. landed into the UK. Of the 4854.8 tonnes of fish landed only 11.9 tonnes came from ICES statistical rectangle 32E6 (Table 9.43). As a percentage of the landings into the whole of the UK this represents 1.7×10^{-2} % of whelks landed into UK ports.

9.6.1.5 Cockles was the second most prevalent species in the wider landings area, and does not appear in the 10 most prevalent species in ICES rectangle 32E6, the 1827.5 tonnes of shellfish caught in the 3 ICES rectangles represents 7.8 % of landings into the UK.



- 9.6.1.6 Mussels were the third most commonly caught species in the wider Swansea Bay region. Over the five years 559.5 tonnes of mussel species were caught representing 4.1 % of mussel landings into the UK. Whilst crabs were the fourth most prevalent species with 405.1 tonnes caught from 2008 to 2012; none of which were captured in 32E6.
- 9.6.1.7 The fifth most prevalent species in ICES statistical rectangles 32E5, 32E6 and 31E6 was Raja spp. Over the 5 year period 313.1 tonnes of raja spp. were caught representing 2.3 % of fish landed in to the UK. It was the second most prevalent species in Swansea Bay (32E6) with 2.5 tonnes of fish caught over the time period which represents just 1.9×10^{-2} % of UK raja spp. landings.
- 9.6.1.8 A marine traffic survey conducted between 14th and 28 August 2013 indicated that during the survey period, the Project site and the area within 5nm of the Project boundary was being used primarily by vessels steaming to fishing grounds, and not targeted itself. Some fishing activity was witnessed South-West of Port Talbot. Evidence further consolidated the opinions gathered in the baseline report (see Appendix 9.1, Volume 3), indicating that the bulk of fishing within the Bay targets whelks, with some gill netting for bass also occurring. For details of the marine traffic survey see Chapter 14, Navigation Assessment.
- 9.6.1.9 A full summary of the commercial fishing findings is given in Appendix 9.1, Volume 3.

9.6.2 Potential impacts

- 9.6.2.1 The following section describes the potential adverse/favourable impacts in terms of environmental effects on commercial fisheries. Table 9.44 outlines the potential impacts on commercial fisheries. The effect of each potential impact is quantified for commercial fisheries in Table 9.45.

Table 9.44 Potential impacts on commercial fisheries

Potential Impact	Potential Effect
Construction phase	
Short-term exclusion from fishing grounds.	Temporary loss of access to traditional fishing grounds.
Short-term displacement to other fishing grounds.	Temporary displacement of excluded vessels to other fishing areas.
Short-term navigational safety issues.	Temporary risks for fishermen fishing in proximity to the safety zones.
Short-term increase in steaming times.	Increased costs to fishermen due to extra fuel used, additional time spent at sea.
Presence of unintended underwater obstructions and debris.	Potential increased cost to fishermen as a result of gear losses.
Operational phase	
Long-term exclusion from fishing grounds.	Long-term loss of access to traditional fishing grounds.
Long-term displacement to other fishing grounds.	Long-term displacement of excluded vessels to other fishing areas.
Long-term navigational safety issues.	Long-term risks for fishermen fishing in proximity to the safety zones.
Long-term habitat modification.	Creation of habitat heterogeneity due to the introduction of Fish Attracting Devices (FADs) (i.e. seawalls) leading to an increase in fish and



Potential Impact	Potential Effect
	shellfish population and diversity.
Long-term increase in steaming times.	Increased costs to fishermen due to extra fuel used and additional time spent at sea.
Decommissioning phase	
Temporary exclusion/displacement from fishing grounds.	Temporary loss of access to “new” seawall fishing ground and displacement of excluded vessels to other fishing areas.
Navigational safety issues	Possible risks for fishermen fishing in proximity to the safety zones. Potential increased cost to fishermen as a result of gear losses.
Habitat modification	Access to fishing grounds within the Lagoon will be re-instated.
Cumulative	
Cumulative exclusion from fishing grounds.	Long-term loss of access to traditional fishing grounds.
Cumulative increase in steaming times.	Increased costs to fishermen due to extra fuel used, additional time spent at sea.

9.6.3 Construction phase effects

Short-term exclusion from fishing grounds

- 9.6.3.1 As discussed in Appendix 9.1 (Volume 3), the area in which the Project is situated is the target of small scale potting and netting, and is used by a limited number of small inshore vessels (< 10 m length). Two vessels are known to seasonally fish for whelks using static gear within the footprint of the Project.
- 9.6.3.2 Safety working zones are required around the dredging and placing operations. These will be implemented in association with ABP, in respect of Swansea Port, and with Neath Port Authorities. It is anticipated that the safety working zones would be approximately 300 m outside the Lagoon and the entirety of its interior. This would be with the exception of the port channels where access will be maintained at all times for vessels using the channels. When operations are carried out adjacent to the port channel, contact would be made and maintained with the relevant port authorities. The extent of the loss of traditional fishing grounds will evolve over the multi-phase construction period lasting from 2015 – 2018.
- 9.6.3.3 There will be an impact on the limited number of small inshore vessels which currently use grounds within the Lagoon footprint and the 300 m safety zone. The magnitude of the impact on these vessels has been assessed as **Medium** with a significance of **Minor** and confidence of **Probable**.

Short-term displacement to other fishing grounds

- 9.6.3.4 Displacement of fishing activity is only likely to occur for a restricted number of fishing vessels, mostly comprising whelk potters. Lobster potting, which occurs to the west past Mumbles Head, and in proximity of Port Talbot port, will not be affected. Gill netting, is also unlikely to be significantly affected, as many areas surrounding the Bay have suitable morphology for this technique.
- 9.6.3.5 The main effects of relocation of gear to other areas may include: a) an increase in pressure on fish/shellfish populations elsewhere; b) a decrease in landings for vessels already fishing in those areas; and c) interference with activities of other fishermen.



- 9.6.3.6 Owing to the low level of commercial fishing exploitation within Swansea Bay the magnitude of the impact has been assessed as **Medium**, with a significance value of **Minor** and a confidence of **Probable**.

Short-term navigational safety issues

- 9.6.3.7 A detailed navigation risk assessment is being undertaken as part of the Project (Chapter 14: Navigation Assessment) and full safety measures will be implemented during the construction and operation of the Project. Safety issues arising for fishing vessels within the proximity of the construction site may include the following:

- i. towed gear becoming snagged on underwater obstructions;
- ii. collision between fishing vessels and construction vessels;
- iii. collision between fishing vessels and static structures.

- 9.6.3.8 Temporary safety zones will serve to minimise the health and safety risks associated with construction. 'Notices to Mariners' would also be issued by the construction contractor/developer to keep fishermen fully aware of the work schedule and safety areas. Other mitigation measures will include Aids to Navigation, promulgation of information and presence of a guard vessel during construction. Additionally, navigation routes for work vessels will be established and fishing vessels will be routed away from these to minimise the chance of collision. Dolphin piles and a floating boom will be installed outside of the temporary cofferdam during the construction phase and the operational turbine housing. A floating boom will be installed inside the Lagoon around the turbine housing during the operational phase.

- 9.6.3.9 It is anticipated that underwater obstructions associated with the Lagoon will lie wholly within the defined safety zones, or will be appropriately marked, and as a result, should not prove dangerous to fishing vessels. Pre and post construction bathymetric surveys will be undertaken to identify any obstructions or debris present prior to construction which may affect dredging operations or resulting from construction works. The surveys would be carried out within the Lagoon and around (approximately 250m) the Lagoon walls (see Appendix 23.1). Prior to implementation of mitigation, the assessment presented in Chapter 14 (Navigation Assessment) identifies an impact of **minor** adverse for increased vessel to vessel collision risk - with work vessels or with displaced vessels and **major to moderate** adverse for additional vessel to structure allusion risk (this is particularly due to the potential risk associated with the temporary cofferdam). Safe working practices and the mitigation identified above will reduce the impact to **Minor** with a confidence of **Probable**.

Short-term increase in steaming times

- 9.6.3.10 There is the potential for short-term increases in steaming as a result of the physical barrier created by Lagoon, construction vessel traffic and associated 300m safety exclusion zone. Increases in steaming time are predicted to be most significant for vessels travelling across Swansea Bay (i.e. East to West; West to East). The increase in steaming distance between the current situation at low water and the worst-case scenario (i.e. a vessel leaving from Swansea Port and steaming around the 300 m



temporary safety zone to the entrance of the River Neath²) would be roughly 4.5 km (2.43 Nm). At 10 knots this equates to an increase of 15 minutes steaming time. It should be noted that surveys (See Chapter 14: Navigation Assessment) have shown the majority of vessels > 10 m heading in a south-westerly direction, these would not be affected by the scheme.

- 9.6.3.11 This small increase in steaming distance and time would increase costs for those fishermen affected due to extra fuel used and additional time spent at sea.
- 9.6.3.12 Commercial fisheries statistics indicate that the majority of vessels fishing out of Swansea Port are likely to head to open sea in a Southerly or South-Westerly fashion (i.e. fishing in ICES rectangles 32E5 or 31E6). In these cases the impacts of the Project on steaming times of commercial fishing boats are likely to be minimal.
- 9.6.3.13 A limited number of smaller vessels, accessing fishing grounds to the East would be affected by the presence of the Lagoon.
- 9.6.3.14 Consultation with the fishing community has indicated that the amount of fishing occurring within the Bay is very limited. It is understood that five vessels will be supplying evidence indicating long-term fishing interests within the Bay (Wisby, I., pers. comm. 2013).
- 9.6.3.15 Few commercial fishing vessels are expected to regularly cross the Bay from West to East or vice versa. It is acknowledged that there will be a minimal increase in steaming times (approximately 15 minutes at 10 knots), especially for vessels heading East from Swansea Port, but the overall magnitude of the impact is assessed as Low. The Lagoon construction is multi-phase and the extent of the obstruction to commercial fishing vessels evolves with eventual exclusion from the footprint of the Lagoon plus a 300 m safety zone over three years. Due to the fact that vessels are unlikely to face significant increases in steaming time under normal circumstances the magnitude of the impact has been assessed as **Medium** with a significance value of **Minor** and a confidence of **Probable**.

Presence of unintended underwater obstructions and debris

- 9.6.3.16 The presence of objects accidentally lost by survey or construction vessels could represent a hazard to fishing gear. In addition, the presence of seabed obstructions such as anchor placements and spoil could also affect fishing safety and efficiency.
- 9.6.3.17 Debris in nets can be dangerous to fishing crews due to handling issues, and can damage gear or lead to gear loss. Fishing vessels using towed gear would be more at risk than vessels using static gear such as pots, owing to their movement across the ground.
- 9.6.3.18 Evidence indicates that minimal amounts of trawling occurs within Swansea Bay, thus the likelihood of this happening would be low. Effects from the presence of underwater debris are not likely to be significant during the construction or decommissioning phases as the established safety exclusion zones will ensure any vessels fishing within the vicinity of the site are outside the area of effect. Pre and post construction bathymetric

² For this scenario, a worst case assumption has been taken that the construction safety zone of 300m will be located around the entire Lagoon throughout the construction phase. It is anticipated that the safety zone will be mobile, situated around the location of ongoing construction. The zone would not be present around completed works.



surveys, as described previously, will be undertaken to identify any obstructions or debris resulting from construction works within the Lagoon and around (approximately 250m) the Lagoon walls (see Appendix 23.1).

- 9.6.3.19 Safe working practices effectively reduce the magnitude of the impact to **Negligible** with a significance value of **Insignificant** and confidence of **Probable**.

9.6.4 Operational phase effects

Long-term exclusion from fishing grounds

- 9.6.4.1 It is anticipated that no commercial fishing vessels will be able to access the Lagoon unless launched from within the Lagoon under particular permissions.
- 9.6.4.2 There will also be a long-term safety zone (500m) established around the turbine and sluice gate housing of the tidal Lagoon for safety reasons. The demarcation of this will be agreed by the Marine Coastguard Agency (MCA). This safety zone will involve permanent dolphin piles and a floating boom outside and a floating boom on the inside of the Lagoon.
- 9.6.4.3 As discussed for the construction phase, small scale potting and netting occurs within the Lagoon footprint and the area is used by a limited number of small inshore vessels (< 10 m length). Two vessels are known to regularly fish for whelks using static gear within the area.
- 9.6.4.4 There will be an impact on those small inshore vessels which currently use grounds within the Lagoon footprint and turbine and sluice gate safety zone (500m). The magnitude of the impact on these vessels has been assessed as **High** with a significance of **Minor** and confidence of **Probable**.
- 9.6.4.5 As discussed below (Long Term Habitat Modification) the introduction of the seawall, creating a new rocky reef, is likely to bring a net benefit to local marine biodiversity and thus provide opportunities for displaced fishermen. Pool Bay reef, constructed in the mid-1980s, is a good example of how structures can prove beneficial to local biodiversity and commercial fishermen. Following the introduction of the reef, surveys of the area indicated rapid colonisation. Within three hours of the reef being placed shoals of gadoids were found at the site. Lobsters and commercial shellfish were also found to quickly colonise the structure (Jensen, 2002; Lockwood et al., 1991).

Long-term displacement to other fishing grounds

- 9.6.4.6 Fishing vessels will not be able to operate within the bounds of the Project after completion of its construction. As a result all fishing activity currently occurring within the Lagoon footprint has the potential to be displaced to other local fishing grounds.
- 9.6.4.7 Displacement of fishing activity is only likely to occur for a restricted number of fishing vessels, mostly comprising the two whelk potters.
- 9.6.4.8 The main effects of relocation of gear to other areas may include: a) an increase in pressure on fish/shellfish populations elsewhere; b) a decrease in landings for vessels already fishing in those areas; and c) interference with activities of other fishermen.



9.6.4.9 Owing to the low level of commercial fishing exploitation within Swansea Bay the magnitude of the impact of the displaced fishermen onto alternative grounds, has been assessed as **High** with a significance of **Minor** and confidence of **Probable**.

9.6.4.10 As discussed below (Long Term Habitat Modification) the introduction of the seawalls, creating a new rocky reef, is likely to bring a net benefit to local marine biodiversity and thus provide opportunities for displaced fishermen. reducing the potential effect to displaced fishermen to **Insignificant** and confidence of **Probable**.

Long-term navigational safety issues

9.6.4.11 Risks associated with navigational safety are outlined in paragraphs 9.6.3.7 to 9.6.3.9 and also considered in Chapter 14: Navigation Assessment.

9.6.4.12 Mitigation measures will be implemented including: structures posing risks to fishing vessels will be marked and lit to industry standards; Aids to Navigation; development of procedures for adverse weather; additional maintenance and dredging of channels where necessary; and promulgation of information. The Lagoon has also been designed considering aspects such as the potential effects on navigation including wave reflection and flows. A permanent safety zone (500 m) around the turbines of the Lagoon will be established using permanent dolphin piles and a floating boom to minimise potential risks to vessels.

9.6.4.13 Prior to mitigation, the assessment detailed in Chapter 14 (Navigation Assessment) identifies a **minor** adverse impact for Increased vessel to vessel collision risk - especially for vessels in the channel coming out of Swansea and a **moderate** to **minor** adverse impact for additional vessel to structure collision risk. Mitigation measures as described above, will be implemented. However, due to the long term presence of the Project, the residual vessel to structure collision risk remains unchanged as **Moderate to Minor** with a confidence of **Probable**

Long-term habitat modification

9.6.4.14 The introduction of the seawall will result in an increase in habitat heterogeneity, which is likely to bring a net benefit to local marine biodiversity. Evidence indicates that 'artificial reef' structures, similar in design to the Project seawall, can contribute to the marine habitat by providing a surface for epibenthic organisms to colonise and crevices for reef fish (Jensen, 2002). Rock reefs can enhance populations of fish and shellfish of commercial value, such as lobster and cod (Tocci, 1996; Todd et al., 1992). Higher fishing yields have also been attributed to the effects of artificial reefs (Jensen, 2002). Currently the majority of lobster fishing occurs West of Mumbles Head. The additional interstitial habitat created with the introduction of the rock armour could act as habitat for the species.

9.6.4.15 Commercial fishing activity around the perimeter of the Lagoon will be permitted, taking into account safety requirements and the needs of the Neath and Swansea Port navigation channels. This could give the opportunity for specific fisheries to develop further (e.g. lobster), although these are most likely to become viable in the medium to long term as populations of fish and shellfish will need time to establish.

9.6.4.16 Consultation with the fishing community has indicated that some fishermen may be reluctant to pot for lobster in the vicinity of the Lagoon owing to the danger of being too close to the seawall (Wisby, I., pers. comm. 2013). However, further evidence indicates



that fishermen currently pot for lobsters in proximity to the Port Talbot dock entrance, which is very similar in morphology to what is suggested for the current Project. In addition to this it is proposed that a hatchery be established at the western landfill building. Initially the rearing of lobster will be undertaken and it would be proposed that some of these would be released on the Lagoon wall thereby providing further opportunities in terms of enhancing biodiversity and future fishing opportunities. Proposals to encourage the reintroduction of native oyster and also, the lobsters are included as part of the Project and discussed further in Chapter 8 Intertidal and Subtidal Benthic Ecology.

- 9.6.4.17 As a result, there is potential for a positive ecological effect arising from the Project, which may in turn have a beneficial socio-economic effect in terms of fisheries (see Chapter 22 Economy, Recreation and Tourism). Therefore, an impact of **Positive** magnitude is projected, with a significance of **Minor** and a confidence of **Probable**.

Long-term increase in steaming times

- 9.6.4.18 There is the potential for long-term increases in steaming as a result of the physical barrier created by the Lagoon and the associated safety zone (500m) around the turbine housing. Increases in steaming time are predicted to be most significant for vessels travelling across Swansea Bay (i.e. East to West; West to East) due to the location of the proposed construction. The increase in steaming distance between the current low water situation and the worst-case scenario (i.e. a vessel leaving from Swansea Port and steaming around the Lagoon Wall plus the max. 500 m turbine and sluice gate safety zone to the entrance of the River Neath) would be roughly 3.5 km (1.92 Nm). At 10 knots this equates to an increase of 12 minutes steaming time.
- 9.6.4.19 An increase in steaming distance and time would increase costs for those fishermen affected due to extra fuel used and additional time spent at sea.
- 9.6.4.20 Commercial fisheries statistics indicate that the majority of vessels fishing out of Swansea Port are likely to head to open sea in a Southerly or South-Westerly fashion (i.e. fishing in ICES rectangles 32E5 or 31E6). In these cases the impacts on commercial fishing boats are likely to be minimal.
- 9.6.4.21 A limited number of smaller vessels accessing fishing grounds to the East would be affected by the presence of the Lagoon. Consultation with the fishing community has indicated that the amount of fishing occurring within the Bay is very limited. It is understood that five vessels have indicated long-term fishing interests within the Bay (Wisby, I., pers. comm. 2013).
- 9.6.4.22 Few commercial fishing vessels are expected to regularly cross the Bay from West to East or vice versa. It is acknowledged that there will be a minimal increase in steaming times (approximately 12 minutes at 10 knots), especially for vessels heading East from Swansea Port. Owing to the sensitivity of the receptors (i.e. independent vessel owners) the overall magnitude of the impact is assessed as **High**. Due to the fact that vessels are unlikely to face significant increases in steaming time the impact has been assessed as **Minor** with a confidence of **Probable**.
- 9.6.4.23 The Lagoon walls are expected to increase fish/shellfish biodiversity within the Bay and so improve the opportunities for fishing locally.



9.6.5 Decommissioning phase effects

- 9.6.5.1 In the event that the Project does not remain operational beyond its current anticipated operational life (120 years), it is intended to be decommissioned by means of removal of the turbine and sluice gates. This has the potential to change the operational “state” of the Project and is discussed below.

Temporary exclusion/displacement from fishing grounds

- 9.6.5.2 Any decommissioning works on the turbines/sluice gates would be within the existing safety zone (500m) and therefore no impact would be anticipated. The impact is expected to be of **Neutral** magnitude with a significance level of **No impact** and a confidence of **Probable**.

Navigational safety issues

- 9.6.5.3 A navigation risk assessment would be undertaken for any decommissioning works and full safety measures would be implemented during decommissioning of the Project. A temporary exclusion zone would serve to minimise the health and safety risks associated with works. Notices to Mariners (or equivalent) would be issued to keep fishermen fully aware of the work schedule and safety areas.
- 9.6.5.4 The presence of objects accidentally lost by survey or construction vessels could represent a hazard to fishing gears. A post-decommissioning survey would be undertaken within the defined work area, and any obstruction would be removed or appropriately marked. As a result, this should not prove dangerous to fishing vessels.
- 9.6.5.5 Safe working practices effectively reduce the magnitude of the impact to **Negligible** with a significance value of **Insignificant** and a confidence of **Probable**.

Habitat modification

- 9.6.5.6 Fishing vessels will be excluded from the Lagoon during the operation phase. With the removal of the turbines, access would be re-instated, thereby providing additional fishing grounds. Also, access to the Lagoon during adverse weather conditions could provide sheltered fishing grounds for the local fleet. The magnitude of the impact is assessed as **Positive** with a significance value of **Minor** and a confidence of **Probable**.

9.6.6 Cumulative effects

- 9.6.6.1 Potential cumulative effects on commercial fisheries may arise as a result of the interactions between the construction and operation of the proposed Tidal Lagoon development and other projects or activities occurring in the wider region. Projects and activities which may compound the potential impacts of the Lagoon are listed in section 9.5.5.1.

Cumulative exclusion from fishing grounds

- 9.6.6.2 No other projects within the vicinity of Swansea Bay have been identified which would lead to a long-term exclusion from fishing grounds.
- 9.6.6.3 Temporary exclusion of vessels from fishing grounds in the vicinity to dredged channels within Swansea Bay (i.e. River Neath and Tawe), and from the construction site around Mumbles Pier is expected (construction works are anticipated to be complete by 2014



prior to works commencing on the Project), though the impacts of these will be limited to near-shore areas and temporary in nature (i.e. for the construction period only). Additionally, the dredged channels are likely to be seldom fished due to vessel activity.

- 9.6.6.4 The magnitude of the impact has been assessed as **Negligible**, with a significance value of **Insignificant** and a confidence of **Probable**.

Cumulative increase in steaming times

- 9.6.6.5 No additional projects or activities have been identified which would constitute a long-term cumulative increase in steaming times as a result of the interaction between them and the construction at the Tidal Lagoon site.

9.6.7 Outline mitigation/enhancement measures

- 9.6.7.1 As discussed previously a policy of engagement with the local fishing community will be established throughout the construction phase of the Project, to identify and agree appropriate and viable options to, as far as practically possible, mitigate any potential effects associated with the exclusion from fishing grounds as a result of the Project.

- 9.6.7.2 There may be scope to involve local fishing vessels with surveys and other duties as part of the construction of the Project.

Proposed mariculture opportunities

- 9.6.7.3 As part of the Project a number of potential mariculture opportunities are being investigated, which include:

- i. Encouragement of the re-establishment of an oyster fishery to the area (see further details below); and
- ii. creation of a lobster hatchery with placement of lobsters on seawall.

- 9.6.7.4 Prior to construction, oyster dredge trawls of the Lagoon footprint and areas to be disturbed during construction works will be undertaken. It would be proposed that any oysters identified will be translocated to the Centre for Sustainable Aquatic Research (CSAR) at Swansea University whilst construction works are ongoing, where their spawning behaviour and spat development will be monitored. In conjunction with SEACAMS, TLSB are also proposing an oyster enhancement programme as part of the operation of the Lagoon to try and encourage the native enhancement of the oyster in Swansea Bay, with the aim of promoting biodiversity and ecosystem health. Current oyster stocks are low and the remaining population in Swansea Bay consists of relatively old individuals. Once the Lagoon is in operation it is proposed that the spatfall of Swansea Bay oysters is maximised. Oyster which were collected during prior to construction would be placed in spatting ponds inside the Lagoon. Spats from the oysters would be encouraged to settle on cultch. The juvenile oysters on cultch material could then be transferred to areas inside the Lagoon to grow. The Lagoon offers shelter from wave energy which could optimise juvenile oyster growth. Young oysters could also be placed outside the Lagoon and performance in terms of survival, growth and impact on biodiversity will be monitored. Associated with the core aims, the program offers opportunities for other research on the biology and ecology of oysters and the ecosystem services of bivalve reefs. It should be noted that these enhancement measures are still being developed and TLSB will work in conjunction with SEACAMS to develop these proposals.



- 9.6.7.5 It is proposed to incorporate a laboratory/hatchery into the western landfall building which also houses the boating centre. The aim of the lab/hatchery facility would be to initially rear lobster which could be placed onto the Lagoon reef. Opportunities into rearing fish species for release to the environment would also be investigated in the future.
- 9.6.7.6 The above mitigation and enhancements could provide opportunities for the local fishing community. Table 9.45 summarises the potential effects, including residual effects following mitigation, on commercial fisheries.

Table 9.45 Summary of potential effects on commercial fisheries

Impact	Magnitude of impact	Spatial effect of impact	Duration of the impact	Likelihood of occurrence	Significance without mitigation and confidence level (adverse unless stated otherwise)	Mitigation and Enhancement	Residual significance and confidence level (adverse unless stated otherwise)
Construction Phase							
Short-term exclusion of commercial fishing vessels from fishing grounds.	Medium	Footprint evolves over construction phase with eventual exclusion from the footprint of the Lagoon plus safety zone (up to 300m).	Approx. 3yrs	Lagoon footprint is used for small scale potting and netting and by a limited number of small inshore vessels (< 10 m length) based on weather and time of year etc.	Significance – Minor Confidence - Probable	N/A	Significance – Minor Confidence – Probable
Short-term displacement to other fishing grounds.	Medium	Footprint evolves over construction phase with eventual exclusion from the footprint of the Lagoon plus safety zone (up to 300m).	Approx. 3yrs	Unlikely to due low commercial fishing pressure in Swansea Bay.	Significance – Minor Confidence - Probable	The Lagoon walls are expected to increase fish/shellfish biodiversity within the Bay and so improve fishing.	Significance – Minor Confidence – Probable
Short-term navigational safety issues.	High	Footprint evolves over construction phase with eventual exclusion from the footprint of the Lagoon plus safety zone (up to 300m).	Approx. 3yrs	Very unlikely	Significance - Increased vessel to vessel collision risk - with work vessels or with displaced vessels: Minor adverse. Additional vessel to structure allision risk: Major to moderate adverse (see Chapter 14: Navigation Assessment). Confidence - Probable	Additional Aids to Navigation (AtoN), work procedures and planning with respect to other users in the Bay, promulgation of information Notice to Mariners (NtoM), guard vessel; appropriate safety zones during construction, dolphin piles and floating boom around temporary cofferdam	Significance – Minor Confidence – Probable (see Chapter 14: Navigation Assessment)
Short-term increase in steaming times.	Medium (few vessels are expected to regularly cross the Bay from East to West or vice versa).	Footprint evolves over construction phase with eventual exclusion from the footprint of the Lagoon plus safety zone (up to 300m).	Approx. 3yrs	Limited increases in steaming time are likely for those heading east (15 minutes at 10 knots, worst case)	Significance – Minor Confidence - Probable	The Lagoon walls are expected to increase fish/shellfish biodiversity within the Bay and so improve fishing.	Significance – Minor Confidence – Probable



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Impact	Magnitude of impact	Spatial effect of impact	Duration of the impact	Likelihood of occurrence	Significance without mitigation and confidence level (adverse unless stated otherwise)	Mitigation and Enhancement	Residual significance and confidence level (adverse unless stated otherwise)
Presence of unintended underwater obstructions and debris.	Negligible	Working area around Lagoon footprint.	Approx. 3yrs	Very unlikely	Significance – Insignificant Confidence - Probable	Pre and post construction bathymetric surveys.	Significance – Insignificant Confidence – Probable
Operational Phase							
Long-term exclusion from fishing grounds.	High	The footprint of the Lagoon plus safety zone (up to 500m) around the turbines	Long-term	Lagoon footprint is used for small scale potting and netting and by a limited number of small inshore vessels (< 10 m length) based on weather and time of year etc.	Significance – Minor Confidence - Probable	The Lagoon walls are expected to increase fish/shellfish biodiversity within the Bay and so improve fishing	Significance – Minor Confidence – Probable
Long-term displacement to other fishing grounds.	High	The footprint of the Lagoon plus safety zone (up to 500m) around the turbines	Long-term	Unlikely to due low commercial fishing pressure in Swansea Bay.	Significance – Minor Confidence - Probable	The Lagoon walls are expected to increase fish/shellfish biodiversity within the Bay and so improve fishing	Significance – Insignificant Confidence - Probable
Long-term navigational safety issues.	High	The footprint of the Lagoon plus safety zone (up to 500m) around the turbines	Long-term	Very unlikely	Significance -Increased vessel to vessel collision risk - especially for vessels in the channel coming out of Swansea: Minor adverse. Additional vessel to structure collision risk: Moderate to minor adverse. (see Chapter 14: Navigation Assessment)	Mitigation including (full details Chapter 14, Navigation Assessment): Lighting and marking of Lagoon, promulgation of information, additional AtoN,; safety zone around turbine/sluice gate housing, dolphin piles and floating boom around outside and floating boom inside lagoon turbine and sluice gate housing.	Significance – Minor for vessel to vessel collision risk, Moderate to Minor for vessel to structure collision. Confidence – Probable (see Chapter 14: Navigation Assessment)
Long-term habitat	Positive	9.5 km of seawall plus scour protection etc.	Long-term	Likely	Confidence- Probable	N/A	Significance – Minor positive

Tidal Lagoon Swansea Bay plc

Impact	Magnitude of impact	Spatial effect of impact	Duration of the impact	Likelihood of occurrence	Significance without mitigation and confidence level (adverse unless stated otherwise)	Mitigation and Enhancement	Residual significance and confidence level (adverse unless stated otherwise)
modification.					Confidence - Probable		Confidence - Probable
Long-term increase in steaming times.	High (few vessels are expected to regularly cross the Bay, to/ from east/ west).	The footprint of the Lagoon plus safety zone (up to 500m) around the turbines	Long-term	Limited increases in steaming time are likely for those heading east (approximately 12 minutes at 10 knots, worst case)	Significance – Minor Confidence - Probable	The Lagoon walls are expected to increase fish/shellfish biodiversity within the Bay and so improve fishing.	Significance – Minor Confidence - Probable
Decommissioning Phase (removal of turbines and sluice gates)							
Temporary exclusion/ displacement from fishing grounds.	Neutral	A proportion of the Lagoon walls adjacent to the turbines/sluices within operational safety zone (up to 500m).	Short-term	Unknown	Significance – No impact Confidence – Probable	N/A	Significance – No impact Confidence – Probable
Navigational safety issues.	Negligible	A proportion of the Lagoon walls adjacent to the turbines/sluices within operational safety zone (up to 500m).	Short-term	Unknown	Significance – Insignificant Confidence – Probable	N/A	Significance – Insignificant Confidence – Probable
Habitat modification	Positive	The footprint of the Lagoon.	Long-term	Unknown	Significance – Minor positive Confidence – Probable	N/A	Significance – Minor positive Confidence – Probable
Cumulative Impacts							
Cumulative exclusion from fishing grounds	Negligible	Lagoon footprint.	Short and Long-term	Unlikely	Significance – Insignificant Confidence – Probable	N/A	Significance – Insignificant Confidence – Probable



9.7 Recreational Fisheries

9.7.1 Recreational fisheries baseline characterisation

9.7.1.1 Recreational fisheries data was gathered primarily through consultation with local fisheries representatives and individual fishermen. Recreational fishing has included sea fishing and anadromous fish returns.

9.7.1.2 Details of the recreational fishing activity within Swansea Bay is given in Appendix 9.1, Volume 3, information about anadromous fish returns is given in Section 9.4.8 and details of vessel movements are given in Appendix 14.1.

9.7.2 Impacts on recreational fishing

9.7.2.1 The following section describes the maximum potential adverse/favourable impacts on recreational fishing over the different phases of the Project. Where certain alternatives exist, in terms of refining the design of the project within defined parameters (see Chapter 4 - Project Description for details) the option with the worst case effect has been assessed.

9.7.2.2 Table 9.46 summarises the expected impacts on recreational fishing.

Table 9.46 Potential impacts on recreational fishing

Potential Impact	Potential Effect
Construction phase	
Short-term exclusion from fishing grounds	Temporary loss of access to traditional fishing grounds.
Short-term increases in steaming times	Increased costs to charter skippers/ fishermen due to extra fuel used, additional time spent at sea.
Restricted access to shore-based angling	Temporary loss of access to shore-based fishing where the scheme makes landfall.
Reduction in anadromous fish returns	Decreases in the number of salmon and sea trout returning to rivers flowing into Swansea Bay
Operational phase	
Long-term exclusion from the fishing grounds	Long-term loss of boat access to traditional fishing grounds within Lagoon.
Long-term increase in steaming times	Increased costs to charter skippers/ fishermen due to extra fuel used, additional time spent at sea.
Long term navigational issues	The footprint of the Lagoon plus safety zone (up to 500m) around the turbines
Enhancement of fishing opportunities	Increases in fish diversity and populations due to 'artificial reef' effect, and improved accessibility to anglers.
Reduction in anadromous fish returns	Decreases in the number of salmon and sea trout returning to rivers flowing into Swansea Bay
Decommissioning phase	
Re-introduction of fishing grounds within the bounds of the Lagoon for recreational vessels (other than shore-launched).	Re-introduction of charter boat access to fishing grounds within Lagoon.
Cumulative	
Cumulative impacts are thought to be negligible for recreational fishermen, and are likely to be less severe than cumulative effects on commercial fishermen (see section 9.6.6).	

9.7.2.3 Table 9.47 provides a summary on the significance of potential environmental effects on recreational fishing.



9.7.3 Construction phase effects

Short-term exclusion from fishing grounds

- 9.7.3.1 Around six charter fishing boats as well as a limited number of private vessels used for angling presently operate in Swansea Bay, targeting both flatfish (e.g. plaice and dab) and roundfish (e.g. bass)³. Business in the charter fleet is seasonal with more trips booked in the summer. The weather limits options in the winter and the majority of boats (including the private fleet) are limited to the confines of the Bay during this period. In consultation, vessel owners indicated that they are reliant on having access to different parts of the Bay to shelter from adverse weather conditions.
- 9.7.3.2 Recreational fishing vessels will be excluded intermittently from within the footprint of the Lagoon, and surrounding 300 m safety zone from construction works, during construction of the Project (multi-phase construction lasting from 2015 up to 2018).
- 9.7.3.3 A number of habitat characteristics (e.g. substrate and hydrology) within the bounds of the Project are similar to other areas across the Bay. This means that vessels could potentially find alternative fishing grounds.
- 9.7.3.4 Due to the evolving nature of the impact (the extent of lost ground evolves over the construction phase, starting with 300m safety zones around construction works to eventual exclusion from the footprint of the Lagoon plus a 500 m safety zone around the turbine and sluice gate housing on completion), the magnitude has been assessed as Low. The construction phase, with associated 300m safety zone around construction works, is expected to take approximately three years. Due to the fact that vessels are likely to use the affected area infrequently based on weather, time of year, etc. the magnitude of the impact has been assessed as **Medium** with a significance value of **Minor** and a confidence of **Probable**.

Short-term increases in steaming times

- 9.7.3.5 As for commercial vessels, there is the potential for short-term increases in steaming as a result of the physical barrier created by Lagoon, construction vessel traffic and associated 300m safety zone. Increases in steaming time are predicted to be most significant for vessels travelling across Swansea Bay (i.e. East to West; West to East). The increase in steaming distance between the current situation at low water and the worst-case scenario (i.e. a vessel leaving from Swansea Port and steaming around the 300m temporary safety zone to the entrance of the River Neath) would be roughly 4.5 km (2.43 Nm). At 10 knots this equates to an increase of 15 minutes steaming time.
- 9.7.3.6 The boundaries of the safety zones will be temporary and may change depending on the progress of construction.
- 9.7.3.7 The main effect of an increase in steaming time is a negative economic impact, due to higher fuel consumption and additional time at sea.
- 9.7.3.8 Smaller vessels which may cut across the Bay between the dredged channels of Neath and Swansea would be most affected. Boats which use the length of the Neath and Swansea navigation channels, before changing their bearing would be minimally affected.

³ Note: 9 charter boat companies are identified in Swansea on seafishingonline.com



9.7.3.9 Few recreational fishing vessels are expected to regularly cross the Bay from East to West or vice versa. It is acknowledged that there will be a minimal increase in steaming times, especially for vessels heading East from Swansea Port, but the overall magnitude of the impact is assessed as Low. The Lagoon construction is multi-phase and the extent of the obstruction to recreational fishing vessels evolves, , starting with 300m safety zones around construction works to eventual exclusion from the footprint of the Lagoon plus a 300 m safety zone around the operational turbine and sluice gate housing. Prior to completion of the Lagoon the safety zone around construction works would be 300m for approximately three years.

9.7.3.10 Due to the fact that vessels are unlikely to face significant increases in steaming time (approximately 15 minutes at 10 knots, worst case) the impact is expected to be of **Medium** magnitude with a significance level of **Minor** and confidence of **Probable**.

Restricted access to shore based angling

9.7.3.11 The majority of the sea shore and sea wall area to be enclosed by the Lagoon is privately owned by the Swansea Port with no public access, although some limited shore based angling is permitted under permit from the Port where the proposed western arm of the Lagoon seawall makes landfall (Crymlyn burrows). During the construction phase of the Project, intermittent shore fishing in this area will be temporarily affected.

9.7.3.12 The loss of shore-based angling amenity related to restricted access has been assessed as minor due to the temporary nature of the loss, and the size and value of the fishery lost. The Lagoon construction is multi-phase. However, access restrictions for anglers are likely to occur for the full three years. Due to the relatively low value of the amenity lost along with the availability of excellent angling close by (e.g. the west harbour arm at Swansea Port) the magnitude of the impact has been assessed as **Medium**, with a significance value of **Minor** and a confidence of **Probable**.

Reduction in anadromous fish returns and rod-catch

9.7.3.13 As detailed in Appendix 9.1 (Volume 3), salmon and sea trout are the only migratory species that are fished recreationally in the rivers entering Swansea Bay. Following one or more seasons in the marine phase of their lifecycle they must pass through parts of Swansea Bay to spawn in their natal rivers. In doing so, some individuals may pass close to and be affected by Lagoon construction activities. Any mortalities during this phase of migration would impact upon numbers of fish available to the rod fisheries. Salmon and sea trout smolts emigrating from these rivers out to sea at the start of the marine phase of their lifecycle must also pass through the Bay and some may similarly be affected by construction activities. This also could affect the numbers later returning as adults and again would impact on numbers available to the rod fisheries.

9.7.3.14 The impacts of the construction phase on smolt, adult salmon and sea trout migration comprise: increases in suspended sediment, underwater noise, artificial lighting, habitat modification and the dewatering of the temporary coffer dam; all of which have been assessed as Insignificant to Minor impacts following mitigation. Additionally, for sea trout, habitat gain has been judged as a Positive impact of Moderate significance, this is due to their coastal foraging behaviour and the positive effect which the artificial reef created by the sea wall would have on their population.

9.7.3.15 The Lagoon construction is multi-phase, and any potential impact on salmon and sea trout evolves over the three-year construction period (see Section 9.4). In light of the



above, the overall impact on the salmon and sea trout fishery is expected to be of **Low** magnitude with a significance value of **Minor**, and a confidence of **Probable**.

- 9.7.3.16 It is not envisaged therefore that such impacts would have a discernible effect on the population of migrating salmon and sea trout, nor any consequent effect on catches up-river and, as a result, angling club memberships and day and season ticket revenue.

9.7.4 Operational phase effects

Long-term exclusion from fishing grounds

- 9.7.4.1 Recreational fishing from charter and private boats occurs within the bounds of the scheme, especially during the summer months, targeting both flatfish (e.g. plaice and dab) and roundfish (e.g. bass). Swansea Bay is used by local charter boats in winter as it provides sheltered fishing grounds. .
- 9.7.4.2 The Project will exclude recreational fishing vessels from the confines of the Lagoon plus a 500 m safety zone around the turbines, unless they are shore-launched within the Lagoon itself.
- 9.7.4.3 While vessels are likely to use the affected area infrequently based on weather, time of year etc. the loss of fishing grounds has been assessed as being of **High** magnitude due to the importance of the area particularly during unfavourable weather and for smaller boats from the private fleet. The impact has been assessed as **Minor** with a confidence of **Probable**.
- 9.7.4.4 However, the Lagoon walls are expected to increase fish biodiversity within the Bay and so improve fishing locally and the Lagoon seawalls may also provide shelter during unfavourable weather. With these potential benefits, the impact has been assessed as **Insignificant** with a confidence of **Probable**.

Long-term increase in steaming times

- 9.7.4.5 There is the potential for a long-term increase in steaming times to occur as a result of the 9.5km Lagoon seawall and a permanent 500m safety zone around the turbines. However, the increase in steaming distance between the current situation at low water and the worst-case scenario (i.e. a vessel leaving from Swansea Port and steaming around the Lagoon Wall including the max. 500m turbine safety zone around to the entrance of the River Neath) would be roughly 3.5 km (1.92 Nm). At 10 knots this equates to an increase of 12 minutes steaming time.
- 9.7.4.6 Few recreational fishing vessels are expected to regularly cross the Bay from East to West or vice versa. It is acknowledged that there will be a minimal increase in steaming times, especially for vessels heading East from Swansea Port, but the overall magnitude of the impact is assessed as Low. The Lagoon walls are expected to increase fish biodiversity within the Bay and so improve fishing opportunities locally.
- 9.7.4.7 Due to the fact that vessels are unlikely to face significant increases in steaming time the long-term impact is expected to be of **High** magnitude with a significance level of **Minor** and confidence of **Probable**.



Long term navigational issues for recreational vessels

- 9.7.4.8 Chapter 14 Navigation and Marine Transport has assessed the potential effects on long term navigation for recreational vessels.
- 9.7.4.9 Mitigation measures will be implemented including: structures posing risks to fishing vessels will be marked and lit to industry standards; Aids to Navigation; development of procedures for adverse weather; additional maintenance and dredging of channels where necessary; and promulgation of information. The Lagoon has also been designed considering aspects such as the potential effects on navigation including wave reflection and flows. A permanent safety zone (500 m) around the turbines of the Lagoon will be established using dolphin piles and a floating boom to minimise potential risks to vessels.
- 9.7.4.10 The assessment detailed in Chapter 14 (Navigation and Marine Transport) identifies a residual **minor** adverse impact vessel to structure collision risk, with a confidence of **Probable**.

Enhancement of angling opportunities

- 9.7.4.11 An increase in hard-substrate areas will occur as a result of the Project. Evidence indicates that structures built for renewable energy schemes can benefit biodiversity and potentially act as Fish Attracting Devices (FADs) (Inger et al., 2009).
- 9.7.4.12 The increases in fish foraging habitat resulting from the presence of the seawall, and the protection from strong currents, mean that the Project could have a potential beneficial effect to fish populations by acting as a nursery habitat for juvenile fish.
- 9.7.4.13 One of the most important recreational fish species within the area is bass. They are the target of both shore fishermen and boat anglers. Bass are naturally attracted to strong tidal currents and rocky zones (Pickett & Pawson, 1994), and it is expected that the habitat created by the seawall will greatly benefit bass populations.
- 9.7.4.14 During consultations, both tackle shop staff and anglers suggested that the Project, depending on the extent of fishing areas, could have a net benefit for local shore anglers, allowing them to target deeper water species such as cod.
- 9.7.4.15 Enhancement associated with the Project design comprise opportunities for recreational angling off the seawall, this will include accessed for disabled anglers.
- 9.7.4.16 Improved fishing and improved access for angling are a positive impact, and due to the potential benefits to the local economy and angling amenity in general, the significance of the impact has been assessed as being of **Positive** magnitude with a significance value of **Minor** and a confidence of **Probable**.

Reduction in anadromous fish returns and rod-catch

- 9.7.4.17 As described above salmon and sea trout from the rivers Tawe, Neath and Afan need to pass through the Bay and may come into proximity with the operational Lagoon as emigrating smolts or as returning adults. There is therefore potential for the Lagoon to have an impact on the migration and survival of salmon and sea trout into these rivers.
- 9.7.4.18 The impact of the operational phase on salmon and sea trout smolt and adult migration, including entrainment and injury in the turbines, has been assessed as being of Minor significance post mitigation. This is due to the low proportion of fish that are predicted to



pass through the turbines, the relatively fish-friendly design (small number of blades, slow rotation rate and minimum gap runner) of the turbines and the proposed deployment of fish deterrent systems as a mitigation measure.

9.7.4.19 In light of the above, the overall predicted long-term impact on the salmon and sea trout fishery is expected to be of **Low** magnitude with a significance value of **Minor**, and a confidence of **Probable**.

9.7.4.20 It is not therefore envisaged that such an impact would have a discernible effect on the population of migrating salmon and sea trout, nor any consequent effect on angling catches and, as a result, fishing club memberships and day and season ticket revenue.

9.7.5 Decommissioning phase effects

9.7.5.1 In the event that the Project does not remain operational beyond its current anticipated operational life (120 years), it is intended to be decommissioned by means of removal of turbine/slucice gates. This has the potential to change the operational “state” of the Lagoon and therefore this circumstance is discussed below.

Loss of access during removal of turbines

9.7.5.2 Any decommissioning works on the turbines/slucice gates would be within the existing safety zone (500m) and therefore no impact would be anticipated. The impact is expected to be of **Neutral** magnitude with a significance level of **No impact** and a confidence of **Probable**.

Re-introduction of Lagoon fishing grounds to larger recreational vessels

9.7.5.3 Recreational fishing is known to occur directly within the bounds of the Project, especially during summer months. The re-opening of the Lagoon to the external sea area may allow access for charter boats etc. Seawall access for recreational fishing would continue from the adjacent areas. The impact is likely to be of **Positive** magnitude, leading to a significance of **Minor**.

9.7.6 Cumulative impacts

9.7.6.1 No cumulative impacts have been identified which would have an effect on recreational fisheries.

9.7.7 Outline mitigation measures

Continued engagement with recreational fishing stakeholders

9.7.7.1 As with commercial fisheries, a policy of engagement with the local recreational fishing community will be established throughout the construction phase of the Project, to identify and agree appropriate and viable options to, as far as practically possible, mitigate any potential effects associated with the Project.

Fishing platforms and other infrastructure

9.7.7.2 Fishing platforms will be included in the Project design. However, their number and extent are still to be determined. For health and safety reasons access during adverse weather conditions would be restricted.



- 9.7.7.3 Opportunity for shore based anglers to fish in deeper water than they currently have access to will result from the presence of the seawall acting as an artificial reef. Examples of artificial reef construction elsewhere show very rapid colonisation by marine flora and fauna, for example in Poole Bay (Dorset), Lockwood et. al. (1991 recorded 160 taxa within 16 months of construction, and accumulation of fish within hours depositing reef blocks. Once the 'reef' habitat has become established, the seawall should therefore increase the number of species that can be targeted by anglers.
- 9.7.7.4 It is anticipated that the seawall will be open to recreational fishermen, and provide a new fishing area. Fishing activity will be subject to weather conditions. Other structures similar to the proposed breakwater (e.g. Brighton Marina Breakwater) operate policies in which closures are decided 24 hours ahead of worsening meteorological conditions. In order to allow safe fishing it is foreseen that a similar approach will be used.

Table 9.47 Summary of potential effects on recreational fishing

Receptor / Impact	Magnitude of impact	Spatial effect of impact	Duration of the impact	Likelihood of occurrence	Significance without mitigation and confidence level (impacts are adverse unless stated)	Mitigation and Enhancement	Residual significance and confidence level (impacts are adverse unless stated)
Construction Phase							
Receptor: Boat-based angling Impact: Temporary exclusion of recreational fishing vessels i. Vessels unable to fish grounds in affected areas. ii. Limits the ground available in the Bay to shelter from unfavourable weather.	Medium	Footprint evolves over construction phase with eventual exclusion from the footprint of the Lagoon plus 300 m safety zone.	Approx. 3yrs	Vessels are likely to use the affected area infrequently based on weather, time of year etc.	Significance – Minor Confidence - Probable	N/A	Significance – Minor Confidence – Probable
Receptor: Boat-based angling Impact: i. Short-term increases in steaming for recreational fishing vessels. ii. Increased costs to charter skippers/ anglers due to extra fuel use and additional time spent at sea.	Medium (few vessels are expected to regularly cross the Bay from East to West or vice versa).	Footprint evolves over construction phase with eventual exclusion from the footprint of the Lagoon plus 300 m safety zone.	Approx. 3yrs	Limited increases in steaming time are likely (approximately 15 minutes at 10 knots, worst case).	Significance – Minor Confidence - Probable	N/A	Significance – Minor Confidence - Probable
Receptor: Shore-based angling Impact: i. Restricted access to shore-based angling during construction. ii. Loss of amenity.	Medium	Limited area of shore and Eastern harbour wall at Swansea Port.	Approx. 3yrs	Low	Significance – Minor Confidence - Probable	N/A	Significance – Minor Confidence - Probable
Receptor: Salmon and sea trout fisheries Impact: i. Reduction in salmon and sea trout returns.	Low (the construction phase is assessed to have a Minor impact on salmon and sea	River Tawe, Neath, Afan and Kenfig catchments	Approx. 3yrs	Unlikely (mitigation measures will reduce the impact of the	Significance – Minor Confidence - Probable	Good practice guidelines for construction works e.g. piling, dredging.	Significance – Minor Confidence - Probable

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Receptor / Impact	Magnitude of impact	Spatial effect of impact	Duration of the impact	Likelihood of occurrence	Significance without mitigation and confidence level (impacts are adverse unless stated)	Mitigation and Enhancement	Residual significance and confidence level (impacts are adverse unless stated)
ii. Reduction in revenue for fishing rights owners, lease holders and angling clubs.	trout and an insignificant impact on returns).			construction phase to insignificant levels).			
Operational Phase							
Receptor: Boat-based angling Impact: Long-term exclusion of recreational fishing vessels (other than shore-launched): i. Vessels unable to fish grounds in affected areas. ii. Limits the ground available in the Bay to shelter from unfavourable weather.	High	The footprint of the Lagoon plus a 500 m safety zone around the turbines.	Long-term	Vessels are likely to use the affected area infrequently based on weather, time of year etc.	Significance – Minor Confidence - Probable	The Lagoon walls are expected to increase fish biodiversity within the Bay, so improve fishing. The Lagoon may also provide sheltered fishing grounds during unfavourable weather.	Significance – Insignificant Confidence - Probable
Receptor: Boat-based angling Impact: i. Long term navigational issues for recreational vessels.	High	The footprint of the Lagoon plus a 500m safety zone around the turbines	Long-term	Additional vessel to structure collision risk: Minor adverse. (see Chapter 14: Navigation and Marine Transport)	Significance: Minor Confidence: Probable	Lighting and marking of Lagoon, promulgation of information, additional AtoN, development of procedures for adverse weather; safety zone around turbine housing, additional maintenance, works vessel co-ordination and guard vessels during major dredging of channels where necessary.	Significance – Minor Confidence - Probable

Tidal Lagoon Swansea Bay plc

Receptor / Impact	Magnitude of impact	Spatial effect of impact	Duration of the impact	Likelihood of occurrence	Significance without mitigation and confidence level (impacts are adverse unless stated)	Mitigation and Enhancement	Residual significance and confidence level (impacts are adverse unless stated)
						Dolphin piles and floating boom around outside of turbine housing and floating boom inside lagoon around turbine housing.	
Receptor: Boat-based angling Impact: i. Long-term increase in steaming times as a result of the Lagoon seawall ii. Increased costs to charter skippers/ anglers due to extra fuel used, additional time spent at sea	High (few vessels are expected to regularly cross the Bay from East to West or vice versa).	The footprint of the Lagoon plus a 500 m safety zone around the turbines.	Long-term	Limited increases in steaming time are likely (approximately 12 minutes at 10 knots, worst case)	Significance – Minor Confidence - Probable	The Lagoon walls are expected to increase fish biodiversity within the Bay and so improve fishing.	Significance – Minor Confidence - Probable
Receptor: Boat-based angling and Shore-based angling Impact: i. Enhancement of fishing opportunities provided by Lagoon seawall ii. Increases in fish diversity and populations due to 'artificial reef' effect, and improved accessibility for anglers	Positive	A proportion of the Lagoon walls (designs not yet complete)	Long-term	Very likely	Significance – Minor Positive Confidence - Probable	N/A	Significance – Minor Positive Confidence - Probable
Receptor: Salmon and sea trout fisheries Impact: i. Reduction in salmon and sea trout returns. ii. Reduction in revenue for fishing right owners, lease holders and angling clubs.	Low	River Tawe, Neath, Afan and Kenfig catchments	Long-term	Unlikely	Significance – Minor Confidence - Probable	Post-monitoring of smolts to assess predation levels. Use of acoustic fish deterrents.	Significance – Minor Confidence - Probable

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Receptor / Impact	Magnitude of impact	Spatial effect of impact	Duration of the impact	Likelihood of occurrence	Significance without mitigation and confidence level (impacts are adverse unless stated)	Mitigation and Enhancement	Residual significance and confidence level (impacts are adverse unless stated)
Decommissioning Phase							
Receptor: Shore-based angling Impact: Loss of access for angling in vicinity of turbine house.	Neutral	A proportion of the Lagoon walls adjacent to the turbines/sluices.	Long-term	Unknown	Significance – No impact Confidence – N/A	N/A	Significance – No impact Confidence – N/A
Receptor: Boat-based angling Impact: Re-introduction of fishing grounds within the bounds of the Lagoon for recreational vessels	Positive	The footprint of the Lagoon plus a 500 m safety zone around the turbines.	Long-term	Unknown	Significance – Minor Positive Confidence – N/A	N/A	Significance – Minor Positive Confidence – N/A



- 9.7.7.5 In addition to the above, TLSB has considered additional enhancement measures, which might assist anadromous fish returns, with benefits to recreational fisheries as a result. The measures in question are not mitigation, since the effects predicted are not significant in any event.
- 9.7.7.6 Nevertheless, TLSB proposes to provide a scheme to examine fishery improvements including:
- 1) Establishment of a fisheries reference group, including key stakeholders such as river angling organisations, to investigate improvements to the existing Tawe Barrage fish pass;
 - 2) A financial or in kind contribution for the provision of engineering and environmental design expertise to such an exercise; and
 - 3) Subject to (a) a design being produced which demonstrates a material benefit to performance of the existing Tawe Barrage fish pass in terms of the numbers of fish passing over the fish pass and (b) securing match funding for such improvements, funding for provision of an improved fish pass.

9.8 Conclusion

- 9.8.1.1 Chapter 9 describes the predicted construction, operational and decommissioning effects of the Project on the ecology of fish and shellfish within the area of the Lagoon and Offshore Works and the wider area, and on commercial and recreational fishing interests. Receptors that include designated species, along with commercial and recreational fish and shellfish resources have been identified through an initial desk study, as well as field surveys.
- 9.8.1.2 Recreational, commercial and migratory fisheries are an important consideration within Swansea Bay and the wider area. To understand the environment without the Project, a review of existing fisheries information and a number of field surveys have been conducted. The field surveys carried out in 2013 indicated that species caught were consistent with the results gathered through the desktop study. A total of 55 species of fish were record during the 2013 surveys and the fish population was dominated by pelagic species including sprat and herring, with common demersal species including bass, whiting, dogfish, gobies, juvenile and adult flatfish (dab and plaice), as well as rays.
- 9.8.1.3 The area surrounding the Bay is rich in fish and shellfish, including species of commercial and/or conservation value. Migratory fish (fish which travel back and forth between marine and freshwater bodies during their lifetime) such as Atlantic salmon, allis shad and twaite shad, European eel, river lamprey and sea lamprey, are of high conservation value and move past the Swansea Bay area and into the Bristol Channel to a number of internationally designated sites upstream, some frequent the Bay during their passage. Rivers flowing into Swansea Bay also host good numbers of Atlantic salmon and migratory brown trout stocks, which have been identified as being of national importance. European eel which are considered critically endangered and of international importance are also known to frequent these rivers. There are also a number of regionally important fish and shellfish stocks, including bass, dab, herring, plaice, sole, rays and other elasmobranchs. A number of species are commercially valuable in the area, these include: bass, mullet, rays, sole, plaice, edible crab, spider crab, whelk and lobster. Other shellfish, such as mussel, are also harvested within the Bay.



- 9.8.1.4 There are no formal UK regulatory guidelines for assessing the significance of fish mortality levels caused by the operation of hydropower facilities. No precedent exists for assessing quantitative impact significance of tidal range power schemes on fish, the La Rance scheme in Brittany being the only fully operational example in the western world of comparable scale.
- 9.8.1.5 The principle of assessing impacts of a single power generation facility on marine fish stocks was devised for the assessment of cooling water abstraction impacts at the Sizewell nuclear stations (Suffolk) for the Sizewell 'B' Public Inquiry (Turnpenny, 1988; Turnpenny & Taylor, 2000). No objection was lodged at the Inquiry in relation to predicted fisheries impacts of the power station. This approach is now accepted as best practice for fisheries impact assessments for all coastal- and estuarine-sited power stations in England and Wales (Environment Agency, 2010a).
- 9.8.1.6 This approach, alongside rigorous consultation with regulators and stakeholders has been used in order to assess the potential impacts of the Project.
- 9.8.1.7 During construction there would be potential to affect fish and shellfish populations temporarily and locally through effects such as underwater construction noise and increases in suspended sediment levels, although control measures will be implemented to reduce these where possible.
- 9.8.1.8 The Lagoon will not physically block access to the mouths of any rivers. However, its effects on migratory fish have been investigated. Detailed computer modelling has been undertaken for key migratory and marine fish species, including behaviour modelling (the likelihood of the various fish species coming into the lagoon area and passing through the turbines and sluices) and entrainment modelling (the effect on any fish that pass through the turbines). The size of the turbines (7m in diameter) and low rotation speeds (approx. 67 rpm) mean that there will be large gaps through which fish can pass and the risk to fish populations and runs of migratory fish will be very low. Furthermore, the use of sluice gates will allow free passage of fish in and out of the lagoon in the latter part of the tidal cycle.
- 9.8.1.9 The significance of impacts on the various receptors (VERs) identified in Chapter 9 vary. With various mitigation measures in place, the potential impacts on commercial and recreational angling are likely to be limited in terms of extent and significance. Similarly, the majority of the potential impacts on fish and shellfish VERs have been assessed as being minor or insignificant. Where potentially significant adverse impacts have been identified, for example the impact of turbine passage on herring, associated mitigation measures (in this instance Acoustic Fish Deterrents) will be implemented. Post-construction monitoring will also be undertaken in order to check that any effects remain within expected design limits.
- 9.8.1.10 Herring are known to spawn in the Bay and some presently spawn within the Lagoon area. Suitable spawning substrates will be provided along the outer Lagoon wall to create alternative herring spawning locations to mitigate for that which currently falls within the foot print of the Project.
- 9.8.1.11 There will be some disruption to local fishermen, especially to any who pot within the Project area. During operation, the Lagoon would not be accessible to any fishing vessels which currently use this area of the Bay and therefore this would result in a loss of some fishing grounds within the lagoon footprint.



- 9.8.1.12 The Project would introduce rocky reef habitat which studies have shown to increase fish and shellfish biodiversity. This has the potential to improve ecological and ecosystem diversity within the Bay with consequent beneficial impacts on recreational and commercial angling. The Lagoon walls can also be expected to provide new sea fishing opportunities with consequent benefits in terms of the local economy.
- 9.8.1.13 The Project also seeks to develop mariculture opportunities including oyster farming within the Lagoon and a lobster hatchery resulting in benefits for Swansea Bay's commercial fishermen as well as the local economy.
- 9.8.1.14 The impact of the assessment above has taken account of the design parameters with potential to result in the most detrimental impacts of fish and shellfish, commercial and recreational fisheries.
- 9.8.1.15 In combination, the residual effects from the construction, operation and decommissioning of the Swansea Bay Tidal Lagoon, are not considered to have a significant effect on the majority of fish and shellfish, commercial or recreational fishing receptors identified.

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